公務出國報告

（出國類別：其他）

經濟部標準檢驗局 97 年度「建置節約能源、再生能源與前瞻能源產業產品標準、檢測技術及驗證平台先期研究及導入計畫」赴日本接受 LED 檢測技術專業訓練暨相關資料蒐集出國報告

服務機關：經濟部標準檢驗局

職　稱：技正、技士

姓　名：葉永宏、邱垂興

地　點：日本東京

出國期間：98 年 4 月 16 至 4 月 25 日

報告日期：98 年 7 月 22 日

摘要

LED 之應用已從傳統指示用途跨入照明領域，具有成為主流照明之潛力。由於 LED 與傳統光源在電性及光學特性等方面差異極大，測試條件、方法與設備亦不盡相同，爰在標準制定與檢測技術方面，充足之資訊（料）與實測經驗極待建立。爰本局 97 年度「建置節約能源、再生能源與前瞻能源產業產品標準、檢測技術及驗證平台先期研究及導入計畫」子計畫 5 之派員出國計畫中，一、LED 室內外照明系統之項目 2 即安排赴日本接受 LED 檢測技術專業訓練暨相關資料蒐集之任務。

此行在資料蒐集方面，於 98 年 4 月 17 日參加「日本 LED/OLED 次世代照明技術國際展覽會」蒐集 LED 相關製程設備、量測設備、產品之資料，與日本及國內等地之參展廠商晤談 LED 技術之進展，體察全球 LED 產業發展情況。在 LED 檢測技術訓練方面，於 4 月 20 日至 23 日假日本品質保證協會（JQA）接受為期 4 天之 LED 測試理論與實測指導，吸取在檢測方面之經驗。

在產業交流方面，於 98 年 4 月 24 日拜訪日本電球工業會（JELMA），了解日本在 LED 照明相關標準制定進度與計畫、產業標準整合經驗、驗證制度等議題交換意見，對於日本在 LED 產品之法規與制度面獲得基本之認識。

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一、 目的

LED 之應用已從傳統指示用途跨入照明領域，具有成為主流照明之潛力。由於 LED 與傳統光源在電性及光學特性等方面差異極大，測試條件、方法與設備亦不盡相同，爰在標準制定與檢測技術方面，充足之資訊、資料與實測經驗極待建立。

由於 LED 屬指向性及高輝度之光源，與雷射（laser）在光學特性上潛藏許多光輻射危害性，爰進行人體之光生物性危害評估至為必要。IEC 60825-1「雷射產品安全-第 1 部：設備之分類及要求」及 IEC 62471「光源與光源系統之光生物性安全」，即為人體光生物性危害評估之重要依據，而歐盟及美加地區均對輸往當地之相關產品加以要求。有鑒於此，在 LED 照明未來可能大量使用之前提下，保障民眾使用安全為首要課題，建立對技術之認知與實測經驗益顯重要。

基於上述理由，本局 97 年度「建置節約能源、再生能源與前瞻能源產業產品標準、檢測技術及驗證平台先期研究及導入計畫」子計畫 5 之派員出國計畫中，一、LED 室內外照明系統之項目 2 即安排赴日本接受 LED 檢測技術專業訓練暨相關資料蒐集之任務。

此行之目的在於接受 LED 檢測技術專業訓練暨相關資料蒐集。在資料蒐集方面，於 98 年 4 月 17 日參加「日本

LED/OLED 次世代照明技術國際展覽會」及 4 月 24 日拜訪日本電球工業會（JELMA），了解 LED 在照明商品化方面之進展與日本在 LED 照明相關標準制定之進程，在 LED 檢測技術訓練方面，於 4 月 20 日至 23 日假日本品質保證協會（JQA）接受為期 4 天之 LED 測試理論與實測訓練，吸取在檢測方面之實務與經驗。

二、 出國行程

日期	地點	行程說明
4/16（四）	台北-東京	去程（台北→東京）
4/17（五）	東京	參加「日本 LED/OLED 次世代照明技術國際展覽會」
4/18（六）	東京	假日
4/19（日）	東京	假日
4/20（一）	東京	於日本品質保證協會（JQA）進行 LED 量測技術專業訓練 LED 相關標準及驗證制度研討
4/21（二）	東京	於 JQA 進行 LED 量測技術專業訓練 上午：光輻射理論簡介 下午：光輻射量測技術簡介
4/22（三）	東京	於 JQA 進行 LED 量測技術專業訓練 上午：脈衝輻射理論簡介 下午：脈衝輻射量測技術簡介
4/23（四）	東京	於 JQA 進行 LED 量測技術專業訓練 上午：LED 輻射理論與量測技術簡介 下午：綜合實測訓練
4/24（五）	東京	拜訪 JELMA（日本電球工業會）
4/25（六）	東京-台北	回程（東京→台北）

三、 過程

（一） 參加「日本 LED/OLED 次世代照明技術國際展覽會」

「日本 LED/OLED 次世代照明技術國際展覽會」為日本一年一度之光電產業技術交流盛會，除日本本地之廠商外，更吸引全球光電產業之廠商前往展覽、觀摩與交流。

本次展覽會為首次舉辦，今年來自全球各地參與之人數超過 6 萬人次。參展之光電產品涵蓋所有 LED/OLED 照明設計研發及製造時所需設備、元件及材料，透過此展覽會有助於產業商機之拓展並能吸取、蒐集最先端照明技術資訊及資料。

本屆展覽會之舉辦時間為 4 月 15 日至 17 日，地點在日本東京有明國際展覽中心（Tokyo Big Sight, Japan）。參展之產品包括：

♦**照明設備**

- LED
- 有機 EL
- FEL
- 無機 EL
- 其他照明設備

♦**製造設備**

【照明設備適用製造設備】

- 真空蒸鍍裝置
- 晶片切割設備

- 濺鍍設備
- 化學氣相沉積裝置
- 磊晶成長系統
- 氧化製程設備
- 摻雜製程設備
- 退火熱處理設備
- 光阻塗佈設備
- 曝光系統元件
- 蝕刻設備
- 刻劃機
- 晶粒接黏機
- 覆晶接著機
- 打線機
- 熔接機
- 成型機
- 密封製程相關設備
- 其他相關製程設備

【製造工程相關設備】

- 洗淨設備
- 搬運機器人/輸送系統
- 潔淨製程相關產品
- 靜電防制產品
- 水處理相關設備
- 瓦斯/藥品供給設備

♦檢查、測試及評估用設備

- 外觀檢查設備
- 表面檢查設備
- LED 量測設備
- 輝度量測設備
- 熱阻量測設備
- 光色量測設備
- 照度量測設備
- 電流/電壓量測設備
- 壽命測試設備
- 評估設備
- 分析設備
- 評估/分析服務
- 設計/研發/技術
- 其他相關機具

- 光度量測設備
- 系統測試元件

♦元件及材料

【照明設備適用原件及材料】

- 晶體基板
- 電極材料
- 玻璃基板
- 光阻材料
- LED 基板
- LED 晶片
- 電子陶瓷材料
- 有機 EL 材料
- 光罩
- 密封材料
- 吸濕材料
- 反射材料
- 引線架
- 接合線
- 成型材料
- 接合材料
- 點膠材料
- 樹脂
- 銲錫焊接材料
- 散熱材料
- 隔熱材料
- 其他封裝元件/材料
- 螢光粉

【光學元件】

- 鏡片
- 偏光膜
- 光反射鏡
- 光學膜

【驅動用相關元件】

- 驅動 IC
- LSI 控制器
- 電源供應器
- 電路板

♦**設計、分析工具及軟體**

- 機構分析工具
- 熱流分析工具
- 結構分析工具
- CAE
- CAD/CAM
- PLM/CPC
- PDM
- 其他設計工具
- 其他分析工具
- 其他應用軟體

參與之人員背景包括：

- LED 製造商
- 有機 EL 製造商
- FEL 製造商
- 無機 EL 製造商
- 照明燈具製造商
- 其他照明設備製造商
- 背光源製造商
- 汽車製造商
- 汽車電子產品製造商
- 光電產品製造商
- 研究機構/大學
- 照明設計師

參與的廠商除日本、歐美及南韓等國際級大廠外，亦有來自我國、中國大陸及香港的廠商，多偏向於產品應用端，顯見兩岸三地的廠商在 LED 應用在國際間漸漸嶄露頭角，並能佔有一席之地。我國具有 LED 技術領先及產量世界第一的優勢，而中國大陸則有市場廣大之利基，都將成為全球 LED 產業中不可忽視之力量。

本次展覽分為照明及平面顯示技術兩大主題館。在照明技術方面，主題館名稱為 LIGHTING

JAPAN，主要展出項目為 LED/OLED 照明技術產品。在平面顯示技術方面，主題館名稱為 FINETECH JAPAN，主要展出光電產品之顯示應用技術。由於兩場館比鄰而居，在結束 LIGHTING JAPAN 之參觀後，順道參觀 FINETECH JAPAN。

1. LIGHTING JAPAN 參觀紀要

據主辦單位統計，本次展覽約有 218 個參展廠商及 16,395 參觀人次參與。

眾所周知，固態照明（SSL）技術，例如：LED/OLED，具有生態友善（eco-friendly）之特性，因應生態技術之需求不斷成長，全世界相關業者無不引頸期盼此次之展覽活動。本次展覽共有 1634 個來自日本以外之海外廠商參展，相當於參觀人數的十分之一。而 FPD 經貿展（FINETECH JAPAN）共有 696 個廠商參展，並吸引 46,134 人次之參觀人潮，兩項展覽共計達到 62,529 之總參觀人次。

在第一屆 LED/OLED 照明技術展方面，主題為次世代照明技術，分為 4 大區域，分別為：照明裝置/設備技術區、製程設備區、量測/評鑑/檢驗區，以及元件/材料區。

由於本次展覽為首次舉辦，吸引全球各地從事 LED/OLED 照明產業人士前往朝聖。所有最新技術齊

聚於：LUMIOTEC 公司之有機 EL 裝置、ELSTREAM 公司之無機 EL 裝置、SUMITOMO CHEMICAL 公司之 LED 封裝、ISHIZUKA ELECTRONICS 公司之低電流二極體、NATIONAL SEMICONDUCTOR 公司之 LED 驅動器 IC、FUJITECH INTERNATIONAL 公司之 OLED 濺鍍設備，以及 NIPPON ELECTRIC GLASS 公司之 OLED 基質材料等。

在眾多生態友善技術中，許多廠商獨鍾於 LED 及 OLED。來自台灣及德國的廠商集中在「台灣展區」及「德國展區」參展，顯見本次展覽會除了日本本地的廠商外，亦受到許多外國公司的重視。在參觀者中，有十分之一來自國外，包括台灣、南韓、中國大陸、香港、德國及美國。

2. FINETECH JAPAN 參觀紀要

FINETECH JAPAN 為世界最大的 FPD 經貿展，許多產業專業人士及新聞媒體在此項展覽中見證 FPD 尖端技術發展現況，並體驗產業的最新趨勢之走向

在 FINETECH JAPAN 主題館中，聯合 FINETECH JAPAN－第 19 屆 FPD 研發及製程技術展覽暨研討會、第 4 屆 FPD 元件及材料展、TOUCH PANEL JAPAN－第 5 屆國際觸控面板技術展及

Display 2009－第 5 屆國際 FPD 展等 4 項特覽共同舉辦。

在 FINETECH JAPAN－第 19 屆 FPD 研發及製程技術展覽暨研討會方面，此次展覽為世界最大之 FPD 研發及製程技術展，分為 5 大區域，分別為：製程設備區、潔淨製程及 ESD 保護區、檢驗/維修/量測區、薄膜生成/製程區，以及評鑑/試驗/分析區。

在製程設備方面，在製程設備區中，獲得 ADY（Advanced Display of the Year）獎之 LINKSTAR JAPAN 及 MITSUBOSHI DIAMOND INDUSTRIAL 等 2 家公司，展出最新的面板切割機。TOKYO ELECTRON 公司展示各種陣列製程設備，MUSASHI ENGINEERING 公司則展出獲得 ADY 獎之自動封裝供應設備。此區的所有廠商皆吸引眾多參觀人潮。

在檢驗設備方面，在檢驗/維修/量測區及評鑑/試驗/分析區中，可看到許多研發中的新產品。NIKON INSTECH、COGNEX 及 KEYENCE 等 3 家公司特別搭配圖片，展示最新的圖像處理設備。獲得 ADY 獎之 OTSUKA ELECTRONICS 及 OLYMPUS 公司，更是眾所矚目的公司之一，參觀人潮源源不絕。

在薄膜生成及製程設備方面，由於光學膜在 FPD 產業中為品質改善之關鍵要素的其中一項，爰在

薄膜生成/製程設備區，吸引眾多參觀者流連。特別是可彎曲式顯示器之薄膜基質，為此區中最受關注之產品。領導性之大廠，例如：TOSHIBA MACHINE、SAKAMOTO ZOKI、INOUE KINZOKU KOGYO 及 SUMITOMO HEAVY INDUSTRIES MODERN 等公司，皆為參展廠商。

在海外參展廠商方面，由於本次活動為國際性之展覽會，吸引許多海外公司參展。某些廠商選擇獨立展示，其他廠商偏好在地區展場展示，例如德國及南韓皆設置專屬之展場。在德國展區中，由知名廠商如 NOVALED 及 AIXTRON 所推出之 OLED 材料，引起參觀者的高度興趣。在南韓展區中，亦隨時可見絡繹不絕之參觀人潮。

在第 4 屆 FPD 元件及材料展方面，此次展覽為全世界唯一展出 FPD 元件及材料切割設備之展覽，主要分為元件/材料及光學膜等 2 大展區。在元件/材料區中，領導性之廠商，例如：NISSAN CHEMICAL INDUSTRIES、SHIN-ETSU CHEMICAL 及 ASAHI GLASS 等 3 家公司皆展出最新產品。研發及設計部門之工程師則對於切割技術展現濃厚興趣。

在光學膜區中，由於光學膜為面板品質改善之關鍵要素一向為人所熟知，所以在此區中之參觀人潮

一年比一年踴躍。在今年，領導性之廠商，例如：ZEON及OSAKA GAS CHEMICALS等公司皆設置展示點，而 LINTEC 公司則展出 LCD 及觸控面板之光學膜。

在 TOUCH PANEL JAPAN－第5屆國際觸控面板技術展方面，此次展覽為全世界唯一之觸控面板技術展覽，主要分為觸控面板模組及台灣展場等 2 大展區。在觸控面板模組區中，TOUCH PANEL LABORATORIES 公司展出大尺寸（46 吋）及高透明投射電容式觸控面板，MINATO ELECTRONIC 公司則展示不同產品，例如：IR觸控面板、電容式觸控面板、電阻式觸控面板及 IR+聲學脈衝波觸控面板。許多產業專家到場參觀並實際操作體驗。

在台灣展區中，由於許多台灣廠商專注於觸控面板技術舉世皆知，所以在此次展覽中，有許多台灣廠商在台灣展區中參展。

在 Display 2009－第5屆國際FPD展方面，本次展覽展出各種型式之 FPD，包括：LCD、PDP、OLED、FED、LCOS、電子紙、觸控面板等。在本次展覽中，次世代顯示產品最受注目，例如：3D 顯示及電子紙等。WORLD WIDE DISPLAY、MITANI 及 NEWSIGHT 等公司展出最新之 3D 顯示產品。世界領

導廠商，例如：台達（DELTA）及 BRIDGESTONE 則展出電子紙產品。TOSHIBA MITSUSHITA DISPLAY TECHNOLOGY 展出中小尺寸之 LCD 及 3D 顯示器，而 SONY 則展示最新款 LCD、3D 顯示器原型及超薄 OLED 顯示器。許多新聞媒體在最新款 FPD 展示區前佇足攝影，使得參觀動線產生壅塞現象，更可看出受重視的程度。

完成參觀活動後，除取得的有形資料外，無形對 LED 及光電產品之應用與尖端技術，有更為深刻的了解。

（二） 接受 LED 測試理論與實測訓練

財團法人日本品質保證協會（Japan Quality Assurance Organization, JQA）具有多年之雷射 LED、藍光 LED 及白光 LED 之量測經驗，累積豐厚之資源與資料。由於日本在 LED 產值穩居世界第一，對於產品品質之技術全球尚無任何一個國家能望其項背。而日本亦為 ISO 與 IEC 等國際標準化組織之會員國，亦為 IECEE 之 NCB，有機會能參與國際標準之制定及國際檢測技術交流，能與日本專業技術人員面對面溝通，除吸取檢測實務之相關經驗外，更能對國際標準制定動向有所了解，實屬難得之經驗。

98 年 4 月 20 日至 23 日在 JQA 接受為期 4 天之 LED 測試理論與實測指導，由代表 JQA 參與 IECEE ETF（expert task force） 11 之技術專家立原克法擔任講師。訓練課程包括 LED 量測技術及驗證制度研討、光輻射理論與量測技術、脈衝輻射理論與量測技術、LED 輻射理論與量測技術、IEC 60825-1 及 IEC 62471 之技術精要、歐盟與美加相關法規淺析，及 LED 相關實測技術與經驗指導。

內容概述如下：

1. 財團法人日本品質保證協會（JQA）簡介

財團法人日本品質保證協會之前身為 JMI，成立於 1957 年 10 月，係經日本政府通商產業省認可，具有獨立性、公正性之民間檢測及驗證機構。JMI 於 1993 年解散，另成立財團法人日本品質保證協會。JQA 之總部設在東京，除在東京設有關東事業所及南關東事業所外，另在名古屋設有中部事業所，在大阪設有關西事業所及北關西事業所，共有 5 個分支機構。

JQA 為國家授權之產品驗證機構，除可進行 PSE 標章之強制性產品驗證及 S 標章之自願性產品驗證外，另獲政府授權進行依日本工業標準化法核發有關材料結構檢測之 JIS 標章，以及依日本醫藥事務法

所進行之醫療設備檢測業務。

JQA 代表日本之國家驗證機構（NCB）加入 IECEE，並可核發家用電器、資訊技術、電子娛樂設備、照明器具、安全變壓器及電磁相容性（EMC）之 CB 測試報告及證書。JQA 認可 IECEE-CB 體系之會員國所核發，包含有日本區域性差異之電線電纜、電容器、低壓電器、電動工具及電器開關類之 CB 測試報告及證書。

2. 訓練過程概要

（1）4 月 20 日進行 LED 相關標準及驗證制度研討

有關 LED 相關標準部分，整理如下：

由於 LED 屬指向性及高輝度之光源，與雷射（laser）在光學特性上潛藏許多光輻射危害性，爰在標準方面，涵蓋之技術領域包括 LED 量測、雷射安全及人體之光生物性危害評估等。茲將國際間相關標準整理如下。

在 LED 方面，包括下列主要標準：

（a）CIE 127 Measurement of LEDs （2nd ed）

（b）CIE 177 Colour rendering of white LED light sources

（c）IEC 60838-2-2 Miscellaneous lampholders - Part 2-2: Particular requirements - Connectors for LED-modules （d）IEC 61347-2-13 Lamp controlgear - Part 2-13: Particular requirements for d.c. or a.c. supplied electronic controlgear for LED modules

（e）IEC 62031 LED modules for general lighting - Safety specifications

（f）IEC 62384 DC or AC supplied electronic control gear for LED modules - Performance requirements

（g）IESNA RP-16 Nomenclature and Definitions for Illuminating Engineering Addendum

（h）IESNA TM-16-05 IESNA Technical Memorandum on Light Emitting Diode （LED） Sources and Systems

（i）IESNA LM-79 IESNA Approved Method for the Electrical and Photometric Measurements of Solid-State Lighting Products

（j）IESNA LM-80 IESNA Approved Method for Measuring Lumen Depreciation of LED Light Sources

（k）ANSI C78.377A Specifications for the Chromaticity of Solid State Lighting Products

（l）ANSI C82.77-2002 Harmonic Emission Limits － Related Power Quality Requirements for Lighting

（m）JIS C 8152　照明用白光 LED 之測光方法

（n）TS C 8153 LED 模組之電源控制裝置之性能要求

（o）JEL 811 一般照明用之 LED 模組之安全性要求

此外，UL 正積極制定 UL 8750 Outline of Investigation for Light-Emitting Diode （LED）- Light Sources for Use in Lighting Products 中，未來銷往美加地區之 LED 照明產品需先通過此項標準之測試始得上市。

在雷射安全部分，IEC 共制定 IEC 60825 系列國際標準共 11 種，其中與 LED 相關者為 IEC 60825-1 Safety of laser products - Part 1: Equipment classification and requirements。

在光生物性安全方面，以 CIE 制定之 CIE S 009/E:2002 Photobiological Safety of Lamps and Lamps Systems 為主，而 IEC 在 2006 年轉訂為 IEC 62471。

過去 IEC 60825-1（1993 年版）之適用範圍涵蓋雷射與 LED 產品，惟在 2007 年版已將 LED 排除在外。據了解，由於 IEC 62471 已涵蓋 LED，爰 LED 與雷射產品之關係正式分道揚鑣，未來雷射產品與 LED 將分別依不同標準進行測試與評估。在日本方面，已參考 CIE S 009/E:2002 制定為 TS 0038 之產業標準，正在進行 JIS 之轉訂作業中。

對 LED 之光生物性危害評估在國際間日益受到重視，IEC 62471 似無法追隨日新月異之照明技術，爰正

緊鑼密鼓進行 IEC 62471-2 Photobiological Safety of Lamps and Lamps Systems – Part 2: Guidance on manufacturing requirements relating to non-laser optical radiation safety 中，主導者為 TC 76，在日本方面，則由 OITDA（Optoelectronic Industry and Technology Development Association）－財團法人光產業技術振興協會代表參與該技術委員會。而 IEC 制定 IEC 62471 時主導者為 TC 34，制定 IEC 62471-2 之主導者為元參與制定 IEC 60825-1 之 TC 76，角色轉換隱含著 IEC 62471-2 中可能涉及雷射安全方面之技術，值得密切觀察。

有關法規及驗證制度方面，整理如下：

在雷射產品安全管制方面，美國 FDA 之聯邦法規 21 CFR ch.1 之 1040.10 及 1040.11 對於雷射產品之要求有極為嚴謹之規範。廠商需檢附第三方實驗室所核發之試驗報告證明符合要求，並附帶自我宣告聲明書一併送交 FDA 備查，FDA 保留隨時稽查之權力。對醫療用雷射產品方面，FDA 要求須符合 ISO 15004 Opthalmic Instruments - Fundamental Requirements and Test Methods 之要求，而日本已將該國際標準轉訂為 JIS T7332。負責為美國 FDA 進行境內醫療設備銷售管理之醫療設備儀器及輻射健康中心（Center for Devices and Radiological Health ,CDRH），亦發布雷射產品符合 IEC 60825-1 及 IEC 60601-2-22 之指導方針（Laser Products – Conformance with IEC 60825-1, Am. 2 and IEC 60601-2-22（Medical electrical equipment - Part 2-22: Particular requirements for basic safety and essential performance of surgical, cosmetic, therapeutic and diagnostic laser equipment）; Final Guidance for Industry and FDA），供 FDA 及工業界參採。

在日本之驗證制度方面，分為強制性產品驗證及自願性產品驗證。在強制性產品驗證方面，日本「電氣用品及材料安全法（Electrical Appliance and Material Safety Law or DENAN - DENKI YOHIN ANZEN HO）（簡稱 DENAN 法，即“電安法”）」自 2001 年 4 月 1 日起強制實施，取代原先之電氣用品取締法。目前管制之電氣產品共有 453 種，均須標示 PSE 標識始可在在日本銷售及使用。而 PSE 標識又分為菱形及圓形 2 種型式。

電安法所管制的產品分為兩類：指定產品（Specified products, SPs）和非指定產品（Non-specified products, NSPs）。所有指定產品均須經日本經濟產業省（Minister of Economy, Trade and Industry, METI）授權之符合性評鑑機構（CAB）進行型式試驗

及工廠檢查，並取得產品驗證證書，並於產品端標示菱形 PSE 標識（Diamond PSE）；非指定產品亦須符合電安法之要求，可以由申請商自行測試或由第三方實驗室測試並出具報告，不須取得產品驗證證書，在產品端需標示圓形 PSE 標識（Circle PSE），做法類似於歐洲之 CE 標識。生產廠場及各種產品類別每年均須接受一次工廠檢查，證書之有效期限依產品類別分為 3 至 7 年，如需延展，須再次進行產品測試。

在自願性產品驗證方面，即標示 S 標識之產品，檢測依據為附帶日本區域性差異之 IEC 標準。S 標識最初由日本兩個半官方機構－日本品保協會及日本電子電器安全與環境技術實驗室所發起，目前由日本電機與電子器具及零件安全認證指導委員會（Steering Council of Safety Certification for Electrical and Electronic Appliances and Parts of Japan, SCEA）主導，參與之成員包含政府機構、製造商、進口商、零售商、產品驗證機構及消費者代表等 50 個單位及團體。欲取得 S 標識之產品，除滿足安全性之要求外，亦須符合 EMC 之規定，生產廠場並須接受首次及年度之工廠檢查。

日本之 3 種產品驗證標識如下表所示。

標識之圖樣			
標識之名稱	指定產品（SP）之 PSE 標識	非指定產品（NSP）之 PSE 標識	S 標識
適用產品	115 種	338 種	—
性質	強制性		自願性
要求	安全及 EMC		
工廠檢查	需要		
電壓	100/200V（單相），200V （三相）		
頻率	50Hz		

對於光源的管制部分，安定器須取得菱形 PSE 標識，40 W 以下之螢光燈管、白熾燈及安定器內藏式螢光燈泡（即俗稱之省電燈泡）須取得圓形 PSE 標識，目前暫不對 LED 燈泡及 LED 燈管加以管制。

（2）4 月 21 日進行光輻射理論及量測技術研習

對於光輻射理論之重點，茲整理如下：

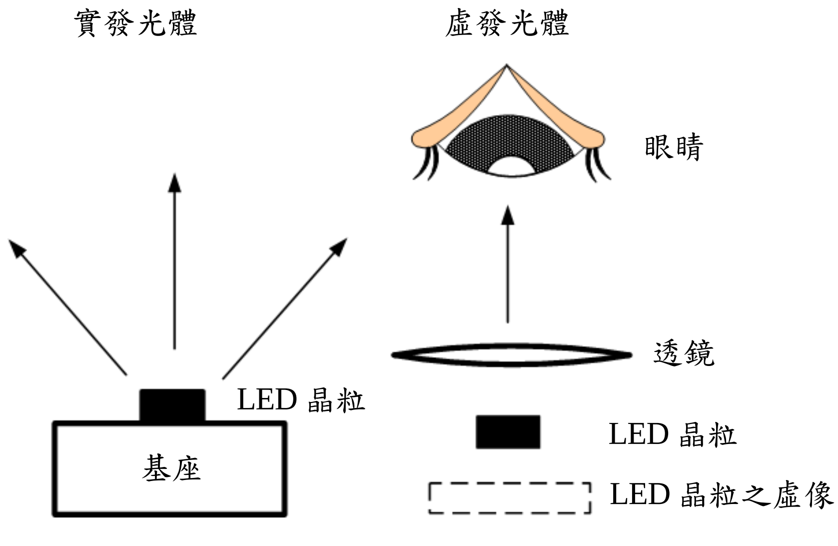
（a）光束：具有方向、發散、直徑或掃描規格之雷射輻射。從非鏡面反射之散射輻射則不視為光束。

（b）可達發射極限（AEL）：依產品所發射之光輻射

特性加以分類，在特定類別內可容許之最大發射位準。

（c）最大允許曝露量（MPE）：正常情況下人體受雷射照射不致產生不良後果之輻射位準。MPE 位準指眼睛或皮膚受雷射照射後立即或經長時間後未發生傷害之最大位準，與輻射波長、脈衝持續時間或曝露時間、處於危險狀態之生物組織，以及曝波長範圍露在 400 nm 至 1400 nm 之可見光及近紅外線輻射中之視網膜影像之大小相關。本次研習重點在於對眼睛之傷害部分。

（d）表觀光源：在視網膜上可能形成最小影像之實際或虛擬物體。觀念如下圖所示。



（e）對向角（angular subtense）：符號為 α，從空間之某一點所觀察到之表觀光源，通常為表觀光源對應於觀察者眼睛或量測點所形成之視角。對向角係指全角，而非半角。為分析最大允許曝露量位

準，對向角須在從表觀光源不小於 100 mm 之觀察距離決定。單位為徑度。

（f）可接受角：符號為 γ，為 1 個光偵測器對光學輻射產生回應之平面角度，通常以弧度表示。可由孔徑或在探測器前之光學元件控制此角度。

（g）光束直徑（光束寬度）：在空間某點處之光束直徑 d_u，係指其功率（或能量）為總雷射功率（或能量）的 u %之最小圓直徑。通常採用 d_{63}。對於高斯光束，d_{63} 對應於輻照度（輻射曝露量）降至其中心峰值 l/e 之點。

（h）光束發散角：由光束直徑之錐形遠場平面角定義。若 2 點間間距為 r 之光束直徑為 d_{63} 及 d'_{63}，則光束之發散角為：

$$\varphi = 2\arctan\left[\frac{d_{63} - d'_{63}}{2r}\right]$$

（i）準直光束：發散角或收斂角極小之平行輻射光束。

（j）擴展光源觀察：在 100 mm 或更遠處之表觀光源對眼睛所成之張角大於最小對向角（α_{min}）的觀察條件。當考慮視網膜熱傷害時，考慮 2 項擴展光源條件：以中間光源及大光源區別對向角 α 介於 α_{min} 與 α_{max}（中間光源）之光源與大於 α_{max}

（大光源）之光源。例如觀察對象為某些漫反射及某些雷射二極體陣列。

（k）輻射亮度（radiance）：在單位發射立體角內，單位輻射面積上之輻射能量，以下式表示。

$$L = \frac{d\Phi}{dA \cdot \cos\theta \cdot d\Omega} \quad (J \cdot m^{-2} \cdot sr^{-1})$$

dΦ 為光束通過某一點在給定方向之立體角 dΩ 中傳輸之輻射通量；dA 為包含該定點之光束截面積；θ 為切面法線和光束方向之夾角。

（l）光譜分佈（spectral distribution）：在波長 λ 處（包含 λ 之波長），間隔 dλ 內之輻射量或光度量 dx（λ）與該波長間隔之商，以下式表示。

$$X_\lambda = \frac{dX(\lambda)}{d\lambda} \quad ([X] \cdot nm^{-1})$$

（m）光譜幅射照度（spectral irradiance）：入射至表面上某單位面積，在一定波長間隔內發出之輻射功率 dΦ（λ），與該表面上之單位面積 dA 及波長間隔 dλ 之商，以下式表示。

$$E_\lambda = \frac{d\Phi(\lambda)}{dA \cdot d\lambda} \quad (W \cdot m^{-2} \cdot nm^{-1})$$

（m）光譜輻亮度（spectral radiance）：通過某一點，並沿某個方向之立體角傳輸之輻射功率 dΦ(λ)與波長間隔 dλ 及該點垂直方向之光束截面積

（ $\cos\theta$ ．dA）以及立體角 dΩ 之商，以下式表示。

$$L_{\lambda} = \frac{d\Phi(\lambda)}{dA \cdot \cos\theta \cdot d\Omega \cdot d\lambda}$$ （$W \cdot m^{-2} \cdot nm^{-1} \cdot sr^{-1}$）

（n）漫反射：輻射光束通過一表面或介質產生多向散射，使輻射光束之空間分布改變。

（o）輻照度：入射至表面上某單位面積中之一點處之輻射通量 dΦ，與該面積 dA 之商，符號為 E。以下式表示。

$$E = \frac{d\Phi}{dA}$$ （$W \cdot m^{-2}$）

（p）最大對向角（α_{max}）：表觀光源對向角之值，當對向角高於該值時，其 MPE 和 AEL 與光源之大小無關。

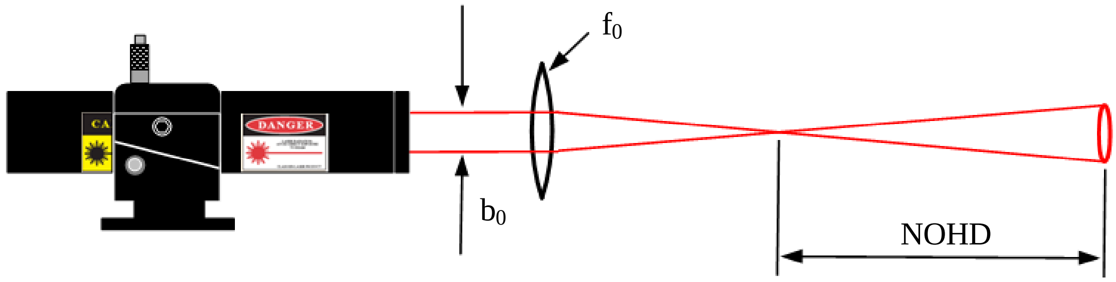
（q）最小對向角（α_{min}）：表觀光源對向角之值，對向角大於該值之光源時視為擴展光源。光源之對向角小於 α_{min} 時，其 MPE 和 AEL 與光源大小無關。

（r）標稱眼睛危害距離（NOHD）：光束輻照度或輻射曝露密度與對應角膜之最大允許曝露量相等之距離。若 NOHD 包括通過光學輔助器觀察雷射光束之可能性時，則定義為擴展 NOHD。

$NOHD=f_0/b_0\times(4\psi/(\pi\times MPE))^{1/2}$，其中，$f_0$ 為光學儀

器之焦距，b_0 為光束之原始直徑，ψ 為光束之輸出功率，MPE 為最大允許曝露量。

NOHD 之示意圖



（s）光化學危害限制：為保護人員不受光化學效應之傷害，對 MPE 或 AEL 所設定之限制。

（t）流明（lumen）：光通量之單位，由一個發光強度為 1 cd 之均勻點光源，在單位立體角內發射之光通量。

（u）勒克斯（lx）：照度之單位，由 I_x 之光通量均勻分布在 1 m^2 表面上所產生之照度。

（v）立體角（solid angle, ω）：在半徑為 d 之球面上，一面積為 A 之圓形曲面（spherical surface area），其周邊對球心的連線所包含的角度為立體角 $\omega=A/d^2$。單位立體角（sr）定義為當 $A=d^2$ 時之立體角。

（w）全光通量（total luminous flux, φ_v）：光源朝所有方向所發出之光通量總和，單位為流明（lm）。

（x）光強度（luminous intensity, I_V）：在指定方向之單位立體角所發射的光通量，單位為燭光

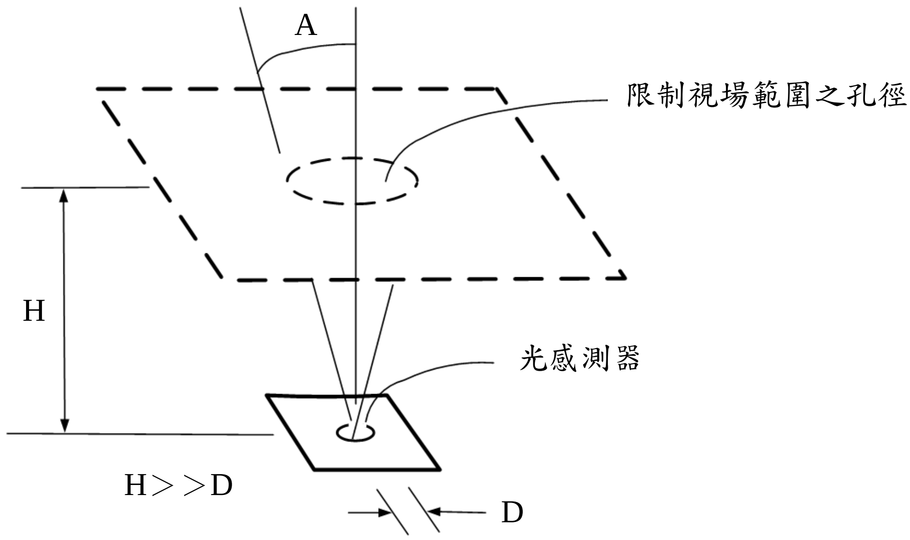
（candela, cd）。

對於光輻射量測技術之重點，茲整理如下：

有關輻照度之量測，以直徑為 D 之光感測器、限制視場之孔徑、分光光譜儀、積分球及數據分析儀進行輻照度量測，以 A 為半角，光源至光感測器之距離，應遠大於光感測器之直徑。數據分析儀應能取得單位接收面積上之入射輻射功率。

就光生物性危害評估之角度，最小輸入孔徑為 7 mm，最大輸入孔徑為 50 mm，可在小型積分球上，開 1 個 25 mm 之圓孔作為單光儀的輸入。對於空間均勻之光輻射源，宜採用 25 mm 的孔徑。對於空間輻射不均勻之光源，光感測器之孔徑應為 7 mm。

輻照度量測之示意圖

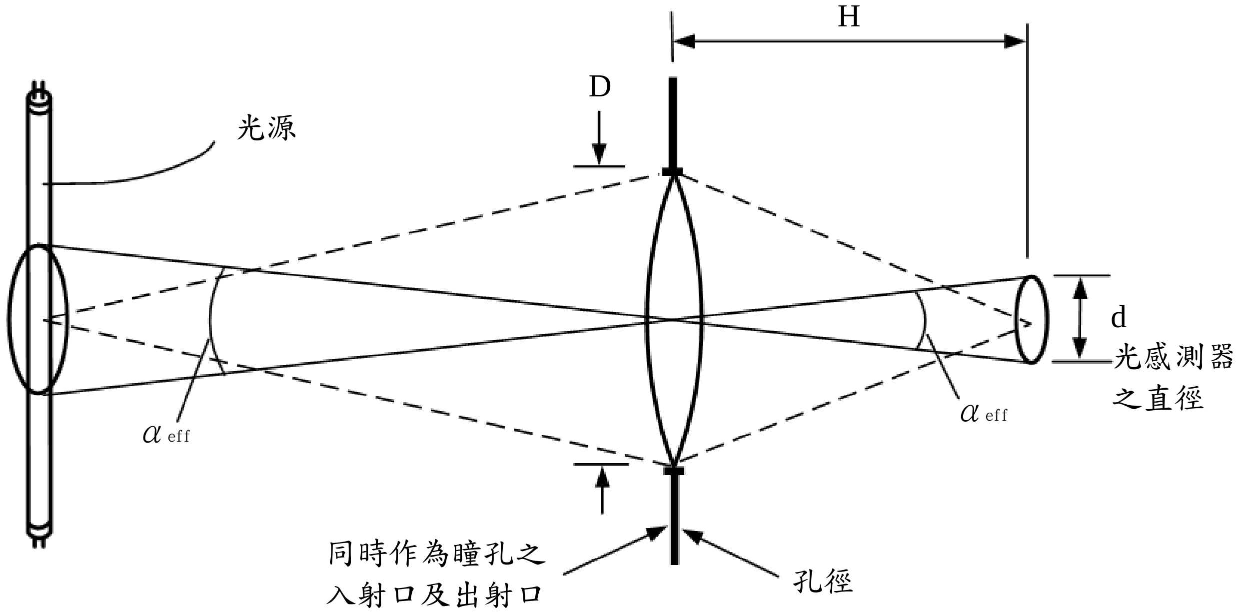


依 IEC 61347 所述，眼睛在靜止狀態時，視網膜之成像最小值為 α_{min}，而將 α_{min} 之值定義為 0.0017 弧度，即以 0.0017 弧度的對向角，作為量測之視場。當

時間大於 0.25 秒時，由於眼睛快速運動而形成更大之視場角度，另定義為 α_{eff}，而 $\alpha_{eff} = \alpha_{min} \cdot \sqrt{(t/0.25)}$ 。

有關輻亮度之量測，以直徑為 D 之光感測器、限制視場之孔徑（角度範圍為 α_{eff}）、分光光譜儀、積分球及數據分析儀進行輻照度量測，光源至光感測器之距離，應遠大於光感測器之直徑。數據分析儀應能取得單位接收面積上之入射輻射功率。對於較小之角度，成像系統中光感測器之直徑與焦距之關係為 $d = \alpha_{eff} H$。入射孔徑 D 對於脈波光源相當於 7 mm 之瞳孔直徑，對於 CW 光源，若入射輻照度足夠均勻，則孔徑可超過 7 mm。

輻亮度量測之示意圖



（3）4 月 22 日進行脈衝輻射理論與量測技術研習

對於脈衝輻射理論之重點，茲整理如下：

（a）第 1 類雷射產品：在對應之波長及發射持續時間內，人員可接近之雷射輻射不容許超過第 1 類 AEL 之任何雷射產品。

（b）第 1 M 類雷射產品：在對應之波長及發射持續時間內，人員可接近之雷射輻射不得超過第 1 類 AEL、波長範圍為 302.5 nm 至 4000 nm 之任何雷射產品。若量測孔徑更小或距離表觀光源更遠時，將比第 1 類雷射產品更須進行危害評估。因此當使用光學儀器觀察時，第 1 M 類產品具有潛在危害性。

（c）第 2 類雷射產品：在對應波長及持續發射時間內，人員可接近之雷射輻射不得超過第 2 類 AEL 之任何雷射產品。

（d）第 2 M 類雷射產品：在對應波長及持續發射時間內，人員可接近之雷射輻射不得超過第 2 類 AEL、波長範圍從 400 nm 至 700 nm 之任何雷射產品。若量測孔徑更小或距離表觀光源更遠時，將比第 2 類雷射產品更須進行危害評估。因此當使用光學儀器觀察時，第 2 M 類產品具有潛在危害。

（e）第 3 R 類及第 3 B 類雷射產品：允許人員接近超過第 1 類及第 2 類 AEL 之雷射輻射，惟在任何發

射持續時間及波長方面，人員可接近之雷射輻射分別不得超過第 3 R 類和第 3 B 類 AEL 之任何雷射產品。

（f）第 4 類雷射產品：人員可接近之雷射輻射容許超過第 3 B 類 AEL 之任何雷射產品。

（g）伴隨輻射：雷射操作時所必然產生，或因雷射操作而使雷射產品發射在雷射輻射以外、波長範圍為 180 nm 至 l mm 之電磁輻射。

（h）連續波（continuous wave, CW）：雷射之輸出波形為連續而非脈衝形式。連續輸出時間在 0.25 秒以上之雷射輻射視為連續波雷射。

（i）發射持續時間：使用、維護或檢修雷射產品時，可能出現人員接觸雷射輻射之單脈衝、脈衝串或系列脈衝之持續時間，或連續波雷射之使用時間。1 個脈衝串其持續時間為首脈衝之第一個半峰值點至尾脈衝之最後半峰值點。

（j）曝露時間：單脈衝、系列脈衝、脈衝串或連續發射之雷射輻射，入射至人體上之持續時間。1 個脈衝串其持續時間為首脈衝之第一個半峰值點至尾脈衝之最後半峰值點。

（k）脈衝持續時間：在脈衝前、後緣之半峰值功率點間測得之時間差。

（l）脈衝雷射：以單脈衝或脈衝串形式釋放能量之雷射。1 個脈衝之持續時間應小於 0.25 秒。

（m）輻射亮度：符號為 L，依下式所定義的量：

$$L = \frac{d\Phi}{dA \cdot \cos\theta \cdot d\Omega} \quad (W \cdot m^{-2} \cdot sr^{-1})$$

其中，dΦ 為由光束通過某一點在給定方向上之立體角 dΩ 中傳輸的輻射通量；dA 為給定點之光束截面積；θ 為切面法線與光束方向之夾角。

（n）輻射能量：符號為 Q，係輻射通量在給定之持續時間 Δt 內，對時間之積分值，如下式所示。

$$Q = \int_{\Delta t} \Phi dt \quad (J)$$

（o）輻射曝露密度：符號為 H，係照射至表面某單位面積上之輻射能量，與該單位面積之商。

$$H = \frac{dQ}{dA} = \int E dt \quad (J \cdot m^{-2})$$

（p）輻射功率/輻射通量：符號為 Φ, P，係以輻射之形式發射、傳輸或接收之功率。

$$\Phi = \frac{dQ}{dt} \quad (W)$$

（q）反射比：符號為 ρ，係在一定條件下反射之輻射功率與入射之輻射功率的比率。

（r）熱危害限制：為保護人員不受熱效應之危害，對 MPE 或 AEL 所設定之限制，與光化學傷害相

反。

（s）曝露限制（exposure limit）：人體特定部位（例如：眼睛或皮膚）所能承受而不致產生不利之生物作用之輻照程度。

（t）視覺的危害距離（ocular hazard distance）：單位為 m，係與光源間之一段距離，若小於此距離，則在一定之輻照時間內，所受之輻射亮度或輻射照度將超過合理之限制值。

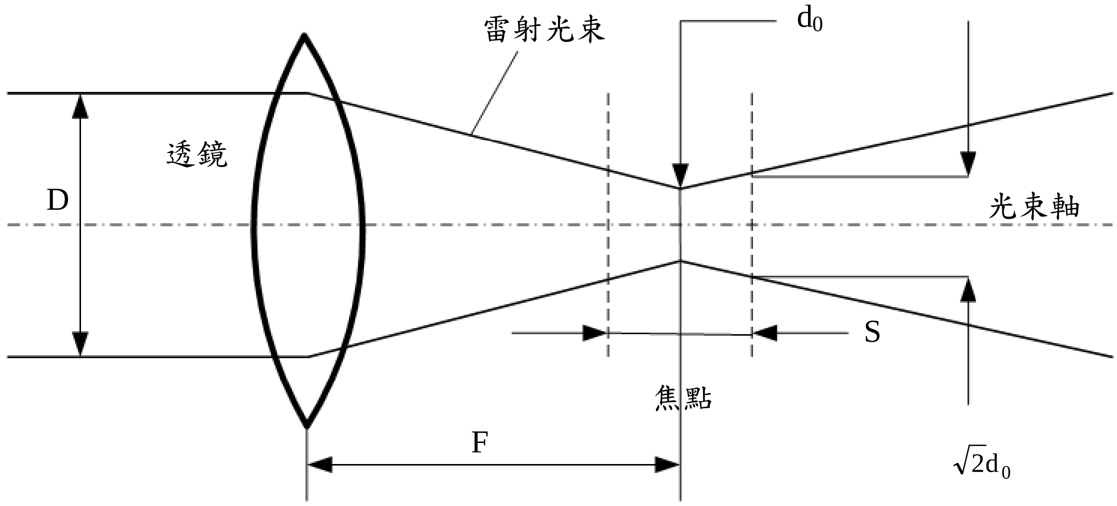
（u）光學輻射（optical radiation）：波長範圍在 X 射線過渡區（波長約為 1 nm）與無線電波（波長約為 105 nrn）之間之電磁輻射。在雷射安全量測領域之範疇，將光學輻射的波段限制為波長大於 200 nm，而 380 nm 至 1400 nm 間之光學輻射將可達到視網膜。

（v）曝露距離（exposure distance）：人體接受照射之最近點與光源間之距離。對於向空間各方向輻射之光源，以光源中心為起點量測此段距離。對於具有透鏡之反射型光源，此段距離從透鏡之外側邊緣起量測，對於無透鏡之反射型光源，自反射器之端面起量測。

（W）光束腰：實際上，雷射光束經透鏡後不會形成無限小的點，經透鏡聚焦後之光束寬度，以 d_0

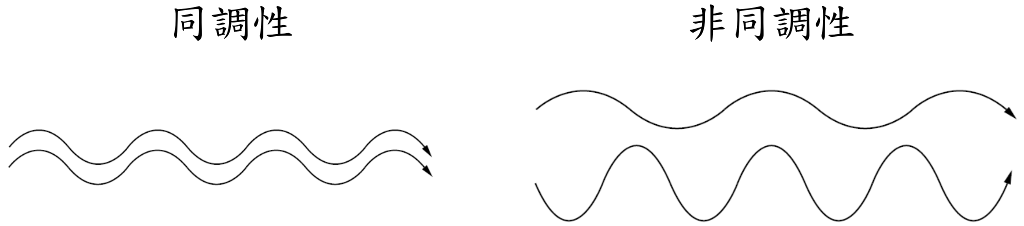
表示。$d_0=2.44\lambda f/D$，其中 D 為雷射直徑，λ 為雷射波長，f 為雷射頻率。下圖中 F 為焦距，而 S 為光束直徑小於 d_0 之範圍，亦稱為焦點深度。

光束腰之示意圖



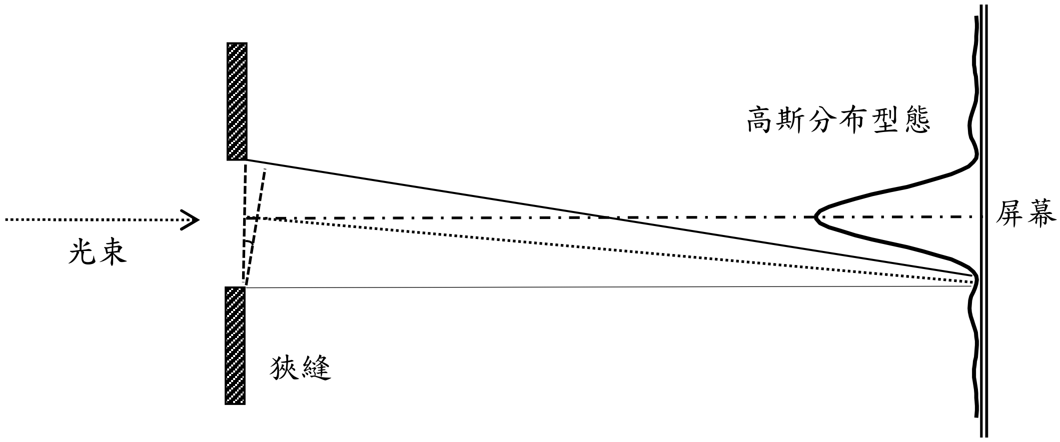
對於脈衝輻射量測技術之重點，茲整理如下：

雷射屬同調性（coherent）之電磁波，由於波峰疊加作用之趨使，具有高能量之特性。

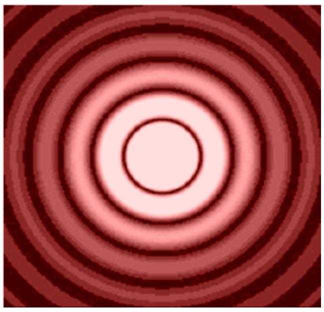


由於光具有波之特性，具有繞射之性質，依單狹縫之試驗結果得知，呈現高斯（Gaussian）分布之型態。在屏幕顯現出明暗相間之條紋。

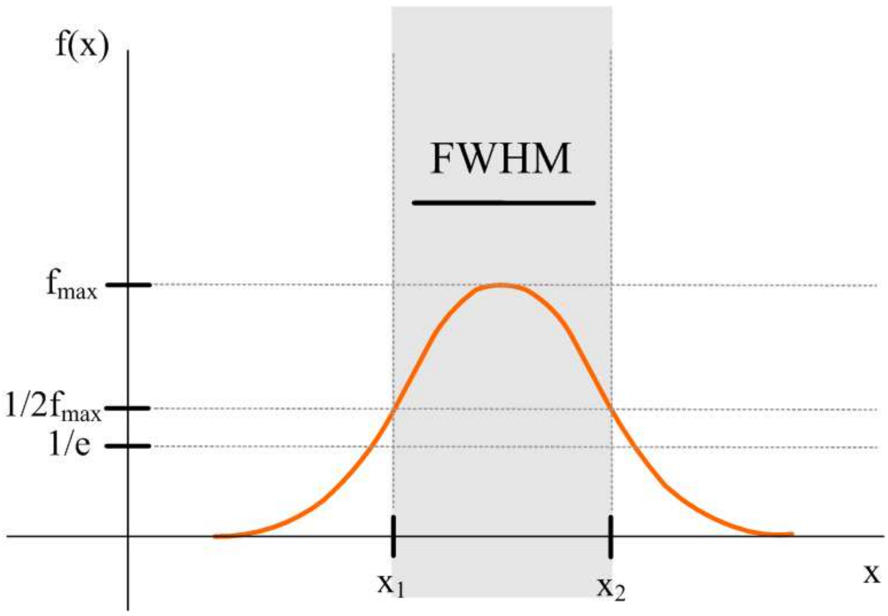
單狹縫試驗示意圖



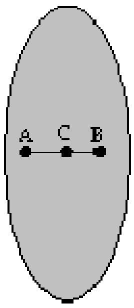
光波之繞射結果



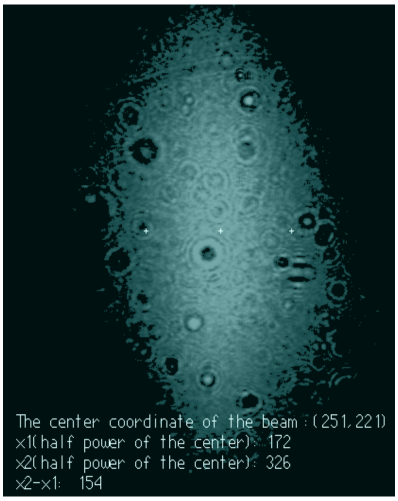
分布之型態如下圖所示。其中 FWHM 為高斯函數半高全寬（Full Width Half Maximum）。從理論面來看，其定義如下圖所示。

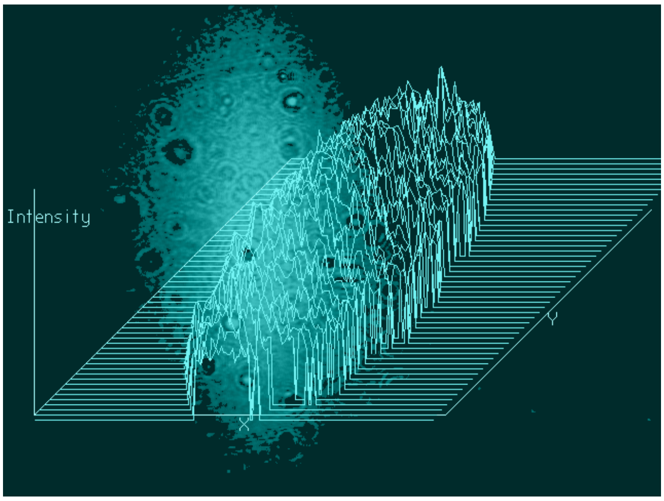


從實務面來看，FWHM 為雷射光束中最高亮度一半處至最高亮度處距離之 2 倍，因此欲求得 FWHM 須先找出整個雷射光束中最亮的位置。藉由掃描整個影像，找出灰階值最亮之點，隨後向右掃描影像，直到找出二分之一亮度處並記錄此處的位置，再以相同的方法向左掃描，並記錄此處之位置，兩位置之間距即為 FWHM。下圖中 C 點為整個光束中亮度最高之位置，而線段 AB 為 FWHM。



下方左圖為量測結果之平面影像，未針對其強度以分色表示，右圖係將左圖之量測數據經電腦分析後，以三維座標顯示強度分布，由圖中可看出中央部位較兩側高之鐘型曲線趨勢，即高斯曲線之型態。

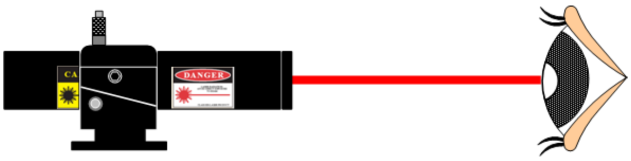


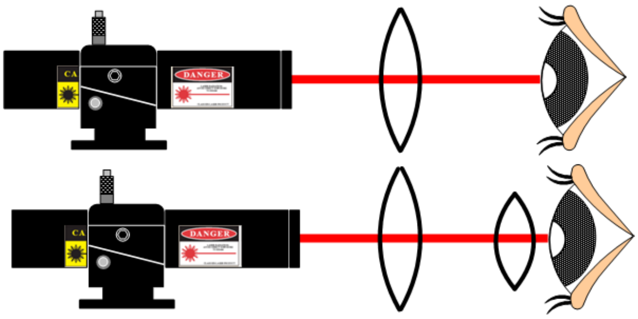


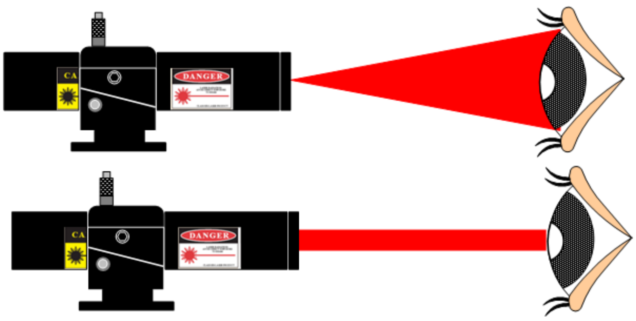
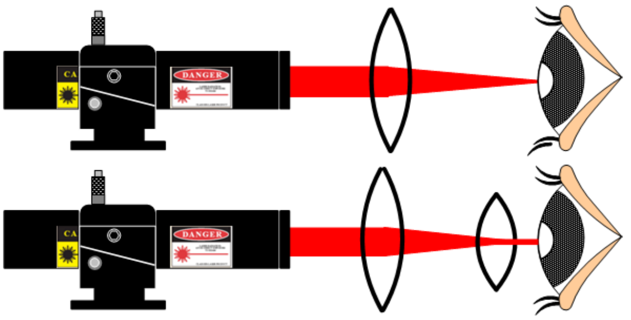
雷射之規格與其造成的危險性有密切關係，IEC 60825-1（已調和為 CNS 15016-1 雷射產品安全－第１部：設備分類、要求和用戶指南）依雷射之危險程度加以分級。雖然透過講師之講授已對標準之觀念有所認識，惟進行光生物安全量測與評估前應從實務面加以考量。依 IEC 62471 所述，就裸視而言，進入眼睛並由視網膜吸收之輻射通量（380 nm 至 1400 nm）與瞳孔之面積相關。在低亮度（小於 0.01 cd・m^{-2}）時，瞳孔直徑約為 7 mm，當亮度達到 10000 cd・m^{-2} 時，瞳孔直徑將縮小至約 2 mm。將最大亮度（對應 0.011 弧度的圓形視場之平均值）小於 10 cd・m^{-2} 之刺激定義為微弱視覺刺激。當亮度大於 10 cd・m^{-2}，且輻射持續時間大於 0.25 時，以 3 mm 之瞳孔直徑（面積為 7 mm^2 ）來評估光生物性危害。當亮度低時，即不產生視覺刺激之情況，以 7 mm 之瞳孔直徑（面積約為 38.5 rnm^2）作為光生物性危害之評估基礎。7 rnm 之瞳孔直徑亦得用於對脈衝光源導致的/或輻射持續時間小於 0.25 秒所導致之光生物危害評估。爰依此原則，將定義再加以釐清，以貼近實際量測之情況。

第 1 類雷射係在合理的操作（包含使用其它觀測用之光學儀器）之下，不致對人體造成安全傷害之雷射。而第 1 M（M 為 Magnification 一詞之縮寫）類雷

射係波長範圍在 302.5 nm 至 4000 nm 間，在合理操作之下，不致造成安全傷害之雷射。若使用望遠鏡或放大鏡觀測時，可能會對人眼造成傷害，其傷害程度須小於第 3 B 類雷射（小於 0.5 W）。第 2 類雷射係波長範圍在 400 nm 至 700 nm，在合理操作之下（包含使用其它觀測用之光學儀器），可藉由自然厭光反應（aversion response，約 0.25 秒）而不致對人眼造成傷害之雷射。波長在 400 nm 至 700 nm 範圍外之第 2 類級雷射，其 AEL 須小於第 1 類雷射之 AEL。第 2 M 類雷射係波長範圍在 400 nm 至 700 nm 間，在合理操作之下，可藉由自然厭光反應而使人眼不致造成傷害之雷射。若使用望遠鏡或放大鏡觀測時，可能對人眼造成傷害，其傷害程度須小於第 3 B 類雷射（0.5 W）。波長在 400 nm 至 700 nm 範圍外之雷射，其 AEL 須小於第 1 M 類雷射之 AEL，始屬第 2 M 類雷射。茲整理成下表。

雷射類別 使用狀況	第 1 類	第 2 類
	安全	照射時間小於 0.25 秒為安全

使用狀況 ＼ 雷射類別	第 1 類	第 2 類
	安全	照射時間小於 0.25 秒為安全

使用狀況 ＼ 雷射類別	第 1 M 類	第 2 M 類
	安全	照射時間小於 0.25 秒為安全
	可能造成傷害	可能造成傷害

第 3R 類雷射係波長範圍在 302.5 nm 至 106 nm，直視雷射光束可能產生傷害之雷射。波長在 400 nm 至 700 nm 之範圍時，第 3R 類雷射之 AEL 須小於第 2 類雷射之 AEL 的五倍，而波長在 400 nm 至 700 nm 範圍

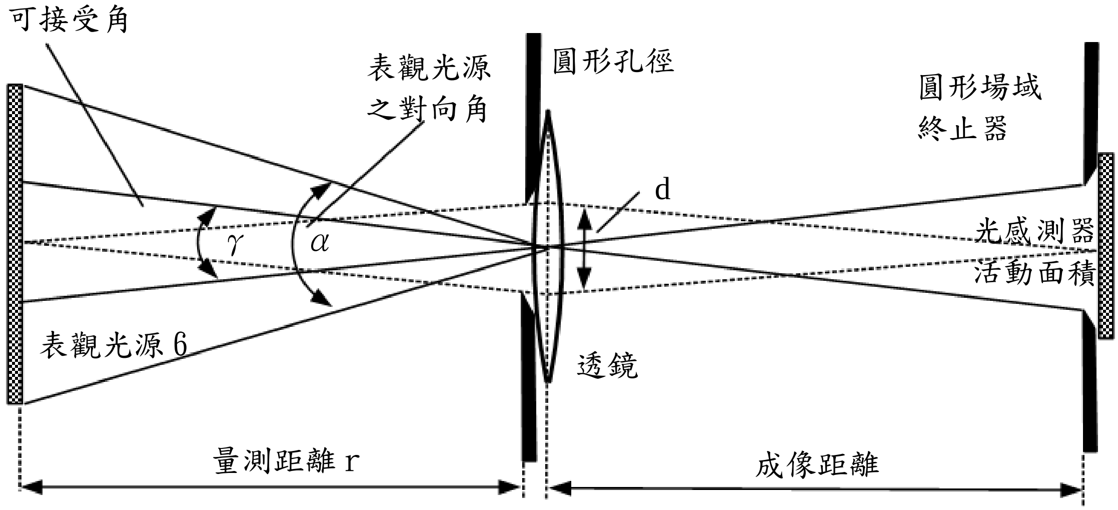
之外時，第 3 R 類雷射之 AEL 須小於第 1 類雷射之 AEL 的五倍。第 3 B 類雷射係直視雷射光束時將造成傷害、惟直視其散射光源仍屬安全之雷射。第 4 類雷射係其散射光束仍具危險性、且可能對皮膚造成傷害並導致火災之雷射。

對於光生物性危害之評估，可接受角 γ 之範圍在時間介於超過 10 秒與 100 秒以下時 γ 為 11 mrad。若光源之對向角 α 大於規定之限制可接受角 γ 時，可接受角不應大於規定值 γ。

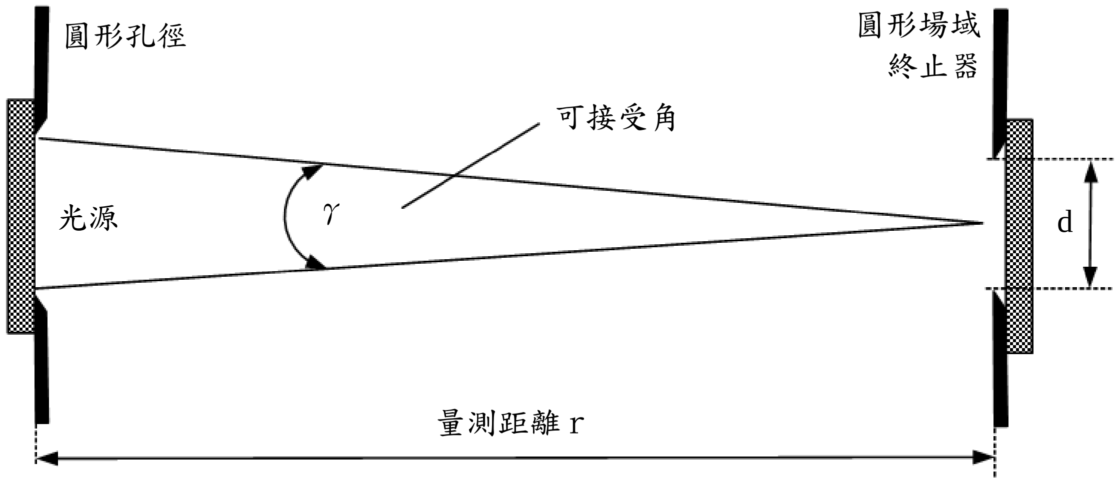
對輻射之量測與光化學限制相較，可接受角 γ 必須考慮完全包括光源（意即可接受角 γ 應至少儘可能大於光源的對向角 α）。然而，若 $\alpha>\alpha_{max}$，處於 302.5 nm 至 4000 nm 之波長範圍內時，可接受角限制為 α_{max}（100 mrad）。在 400 nm 至 1400 nm 之波長範圍內，須評估由多點組成之表觀光源，可接受角在 $\alpha_{min}\leqq\gamma\leqq\alpha_{max}$ 之範圍內變化。

可接受角由場域終止器直徑與透鏡場域終止器距離（成像距離）之比值決定，或由場域終止器直徑與光感測器距離之比值決定，應將透鏡之傳輸及反射之損失考慮在內。終止器量測距離 r 依 IEC 60825-1 表 10 之規定。

表觀光源透過透鏡成像

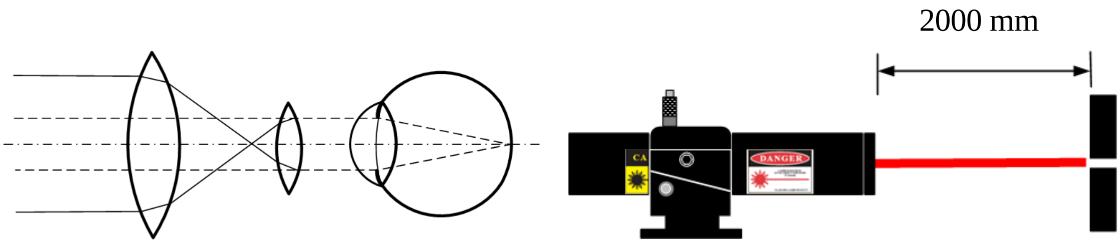


光源不透過透鏡成像

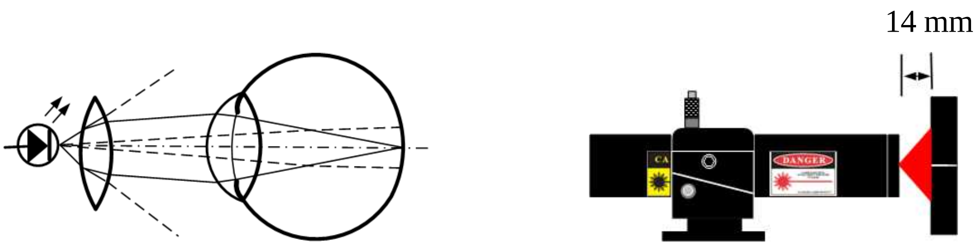


主要量測狀況如下：

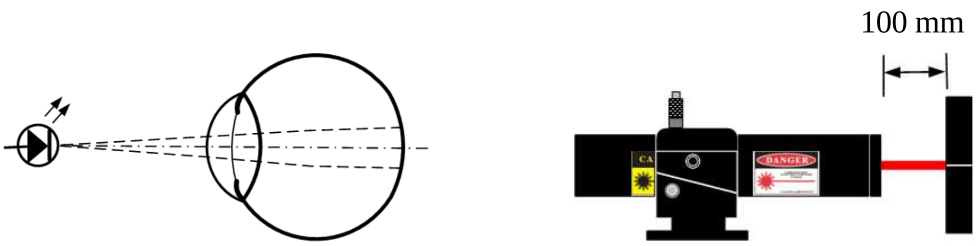
量測狀況一，使用望遠鏡觀測準直光束：以 50 mm 之孔徑模擬人眼透過 7x50 之望遠鏡（最常用的望遠鏡）對雷射光源進行觀測時的結果，以距離雷射光源 2000 mm（即 2 m）遠處設置 50 mm 之孔徑，於孔徑後方量測。



量測狀況二，使用放大鏡觀測發散光源：模擬人眼透過放大鏡，對雷射光源進行觀測時之結果，以距離雷射光源 14 mm 遠處設置 7 mm 之孔徑，於孔徑後方量測。



量測狀況三，視觀測：模擬人眼以裸視觀測雷射光源時之結果，以距離雷射光源 100 mm 遠處設置 7 mm 之孔徑，於孔徑後方量測。



雷射之類別依下列量測條件判定：

（a）第 1 類雷射之量測：若依上述狀況一及狀況二進行量測，所測得的 AEL 不超過 IEC 所規定之「第 1 類雷射之 AEL」，則屬第 1 類雷射。

（b）第 1 M 類雷射之量測：若同時滿足下列 2 項條件，則屬第 1 M 類雷射：

－依上述狀況一及狀況二進行量測，所測得之 AEL 之值超過 IEC 所規定「第 1 類雷射之 AEL」，惟小於「第 3B 類雷射之 AEL」；

－依上述狀況三進行量測，所測得之 AEL 不超過 IEC 所規定之「第 1 類雷射之 AEL」。

（c）第 2 類雷射之量測：若依上述狀況一及狀況二進行量測，所測得之 AEL 超過 IEC 所規定之「第 1 類雷射之 AEL」，惟不超過「第 2 類雷射之 AEL」，則屬第 2 類雷射。

（d）第 2 M 類雷射之量測：若同時滿足下列 2 項條件，則屬第 2 M 類雷射：

－依上述狀況一及狀況二進行量測，所測得之 AEL 超過 IEC 所規定之「第 2 類雷射之 AEL」，惟小於「第 3B 類雷射之 AEL」；

－依上述狀況三進行量測，所測得之 AEL 不超過 IEC 所規定之「第 2 類雷射之 AEL」。

（e）第 3 R 類雷射之量測：若依上述狀況三進行量測，所測得之 AEL 不超過 IEC 所規定之「第 3 R 類雷射之 AEL」，則屬第 3 B 類雷射。

（f）第 3 B 類雷射之量測：若依上述狀況三進行量測，所測得之 AEL 不超過 IEC 所規定之「第 3B

類雷射之 AEL」，則屬第 3 B 類雷射。

（g）第 4 類雷射之量測：若依上述狀況三進行量測，所測得之 AEL 不超過 IEC 所規定之「第 4 類雷射之 AEL」，則屬第 4 類雷射。

（4）4 月 23 日進行 LED 輻射理論與量測技術研習

關於 LED 輻射理論之重點部分，整理如下：

（a）發光二極體（LED）：具有受電能激發時發光之 PN 接面的半導體元件。

（b）部分 LED 光通量（partial LED flux）：在某特定立體角範圍內由 LED 元件所發出之光通量，該立體角之值由一直徑 50 mm 之圓形孔徑及從 LED 元件頂端至孔徑的圓心距離決定之。

（c）平均 LED 光強度（averaged LED intensity）：待測 LED 元件依選定之形式定位，從待測 LED 元件之頂端至光感測器之入射孔徑作為基準面，在指定距離下形成之立體角內所量得之平均光強度值。待測 LED 元件之機械軸應通過照度計頭圓形孔徑之中心。

（d）半光強度發射角（half intensity angle）：LED 元件之光強度分布，由峰值強度向兩側強度降至峰值強度一半之間隔夾角角度。

（e）發光光譜分布（spectral power distribution）：

LED 元件之發光功率對於發光波長的分布。

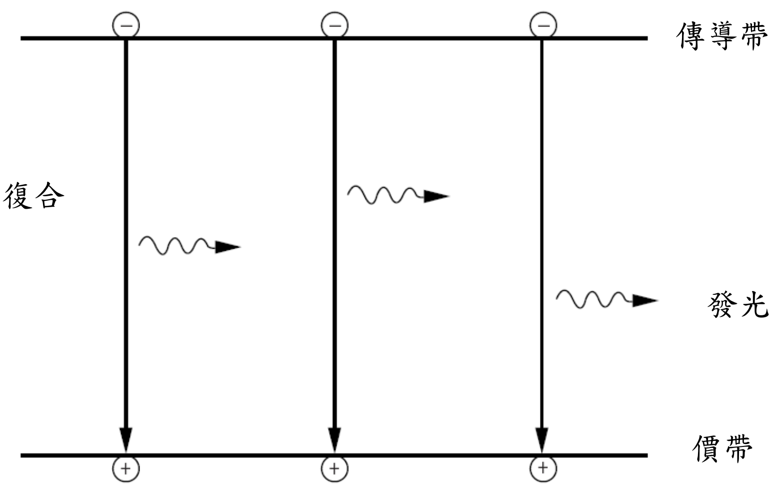
（f）峰值波長（peak wavelength）：發光光譜分布中，發光光譜功率最大值處之波長，單位為 nm。

（g）光譜半高波寬（spectral half-width bandwidth）：

LED 元件之發光光譜分布，由峰值向兩側功率降至一半之間隔波長寬度，單位為 nm。

關於 LED 量測之重點部分，整理如下：

LED 之發光原理係電子（帶負電）受電能激發後，由價帶躍遷至傳導帶，於價帶中留下空位形成電洞（帶正電），在傳導帶之電子隨機返回價帶與電洞結合（稱為復合），在復合之過程中，將能量以光之形式釋放而發光。由於發光二極體為通常為光源中之 1 個發光單元，爰具有點光源之特性，與一般傳統光源與漫射發光之原理不同，量測方法有所差異。



LED 量測通常以光學頻譜分析儀解析其光譜特性，相關參數說明如下：

總功率：以光學頻譜分析儀量測 LED 時，LED 之頻寬遠大於光學頻譜分析儀之解析頻寬（Resolution Bandwidth, RBW）。解析頻寬係指 2 個不同頻率之信號能清楚分辨之最低頻寬差異。光學頻譜分析儀之循跡點（trace point）所顯示之結果為頻譜密度（W/nm）及非絕對功率。由於在整個波長範圍內，狹縫寬度與波長之比值亦導致有效解析頻寬之改變，因此方程式以內校正數據考量上述情況。總功率以右式決定：

$P_o = \sum_{i=1}^{n} P_i (\frac{trace\ point\ spacing}{RBW})$，其中 n 為循跡點數，$P_i$ 為單循跡點之功率值。

3 dB 頻寬：找出 LED 頻譜之峰值點，從該點朝兩側降至 3 dB 之點，即頻譜密度恰等於峰值功率頻譜密度的一半，在此兩點間之寬度即為 3 dB 頻寬。

峰值密度（1 nm）：在峰值波長處，功率頻譜密度以 LED 之 1 nm 頻寬正規化（normalized）後之值。峰值波長在最高循跡點處，對應於 LED 頻譜之峰值。以下式計算：

$$Peak\ Density = \frac{P_{peak}}{RBW_{(\lambda_{peak})}}$$

σ（sigma）：係在高斯分布下，LED 頻譜寬度之

均方根值。以下式計算：

$$\sigma=\sqrt{\sum_{i=1}^{n}\frac{P_i}{P_o}\left(\frac{\text{trace point spacing}}{\text{RBW}}\right)(\lambda_i-\overline{\lambda})^2}$$

其中 $\overline{\lambda}$ 在此視為平均波長（FWHM），λ_i 為單循跡點之波長，P_i 為單循跡點之功率，P_o 為總功率。

平均波長：代表所有循跡點群體之中心波長，以總功率及各循跡點之功率來決定平均波長。以下式計算：

$$\overline{\lambda}=\sum_{i=1}^{n}\frac{P_i}{P_o}\left(\frac{\text{trace point spacing}}{\text{RBW}}\right)\lambda_i$$

中心波長：為決定 3 dB 頻寬之 2 點，其對應波長之平均值。通常平均波長與中心波長相近。

半高全寬（FWHM）：表示 LED 半功率點之頻譜寬度。半功率點為功率頻譜密度恰為峰值一半之點。半高全寬值通常與 3 dB 頻寬極為接近。FWHM=2.355σ。

（5）4 月 23 日進行綜合實測訓練

關於量測設備及儀器之重點部分，整理如下：

（a）擋板：防護罩或防護圍封的一部分。當移去或拆除時，可提供雷射輻射之通路。

（b）孔徑/孔徑光闌（aperture/ aperture stop）：係定義

平均光輻射測量區域之開口，對於光譜輻照度測量而言，開口通常位於輻射度計/光譜輻射度計入射狹縫前方積分球之入口。

（c）限制孔徑：對輻照度和輻射曝露密度進行平均之圓形區域。

（d）光束衰減器：使雷射輻射降至低於規定位準之裝置。

（e）擴束器：可擴大雷射光束直徑之光學組件。

（f）規定光路：在雷射產品內部之雷射光束預定路徑。

（g）光路組件：位於規定光路之光學組件（例如：光束控制鏡或聚焦透鏡）。

（h）光束終止器：終止雷射光束路徑之裝置。

（i）頻譜分析儀：對於量測信號之時域，示波器為重要之量測儀器，可直接顯示信號波幅、頻率、週期、波形與相位之響應變化，惟僅侷限於低頻之信號。高頻信號之量測可透過頻譜分析儀將含有許多頻率之信號以頻域方式呈現，以識別在各個頻率之功率，顯示信號在頻域中之特性。

（j）解析頻寬：2 個不同頻率之信號頻寬如低於頻譜分析儀之 RBW，則兩信號將重疊且難以分辨，較低之 RBW 固然有助於不同頻率信號之分辨與

量測，惟低 RBW 將濾除較高頻率之信號成份，導致信號顯示時產生失真，失真值與所設定之 RBW 密切相關，較高之 RBW 雖有助於寬頻帶信號之偵測，惟將增加雜訊底層值(Noise Floor)，降低量測靈敏度，對於偵測低強度的信號易產生阻礙，爰適當之 RBW 寬度為正確使用頻譜分析儀之重要概念。

（k）主要量測設備應符合下列基本要求：

－量測用電源：直流電源之漣波（ripple）百分率在 1%以下，變化率應在±0.2%以內。

－電性量測用儀器：容許差需在±0.5%以內。

－分光光譜儀（spectroradiometer）：對所量測之波長範圍具有必要之帶域特性，並具有充分的解析能力者。頻寬及波長之掃描間隔應小於 2.5 nm。波長精確度須在±0.3 nm（以汞氬燈或雷射比對）以下。

－積分球（integrating sphere）：內部應具備相同之白色擴散反射特性。球體內壁反射率須大於 90%，量測部分 LED 光通量時，內壁反射率須大於 95%，總開口埠面積須小於球體內壁面積的 4%。

所使用之量測設備/儀器如下：

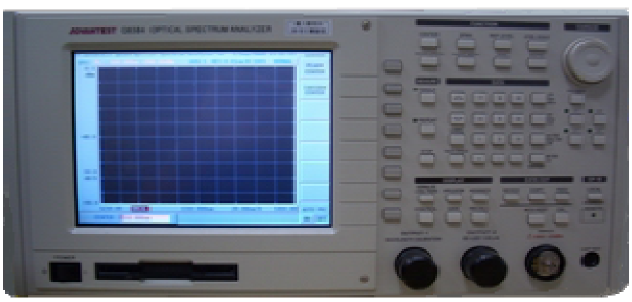
氦氖雷射產生器

藍光/白光 LED 元件

電源供應器

溫度控制器

光學頻譜分析儀



光感測器

分光光譜儀

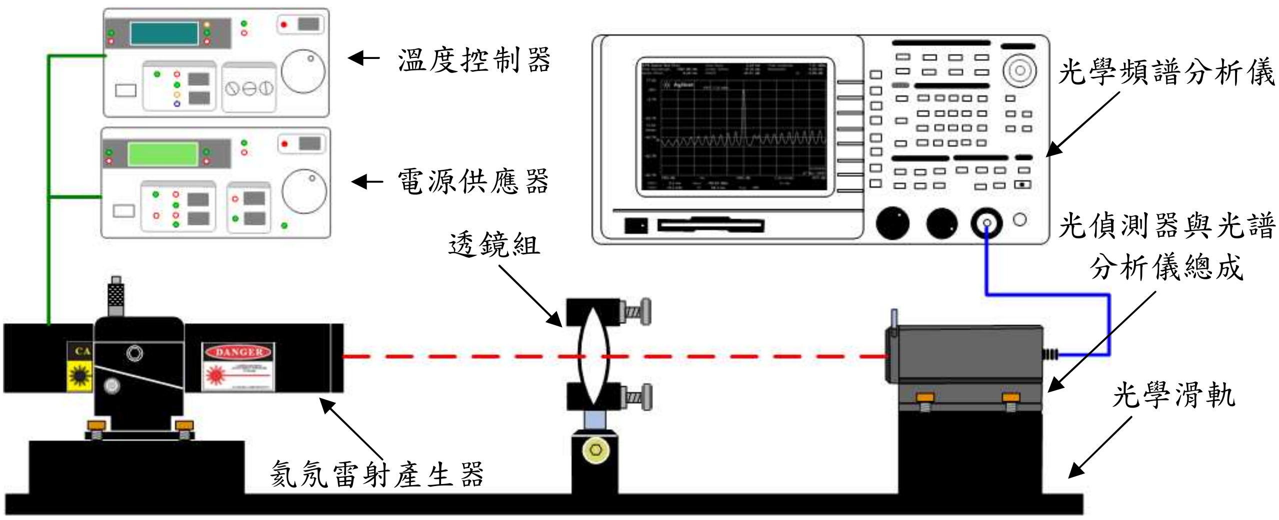
固定座

手持式觀測器

積分球

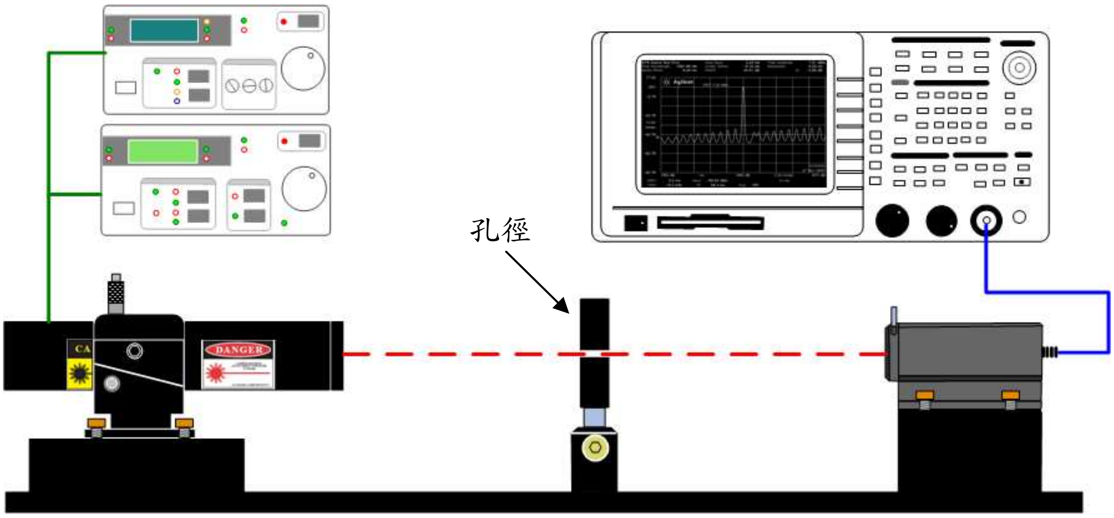
首先進行表觀光源透過透鏡成像之量測，設備之配置如下圖所示。隨後將透鏡組移去，進行光源不透過透鏡成像之量測。

使用透鏡進行雷射之量測

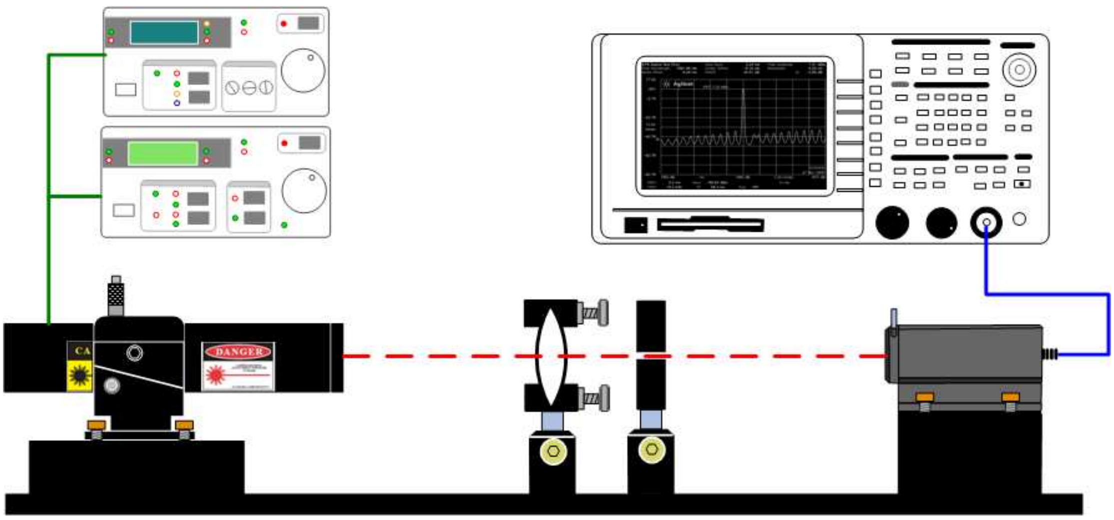


依雷射類別進行量測，以孔徑模擬人體之瞳孔，進行雷射安全之評估。另以透鏡模擬使用放大鏡或望遠鏡觀測之情況，進行危害評估。量測之配置如下圖所示。

使用孔徑進行雷射之量測



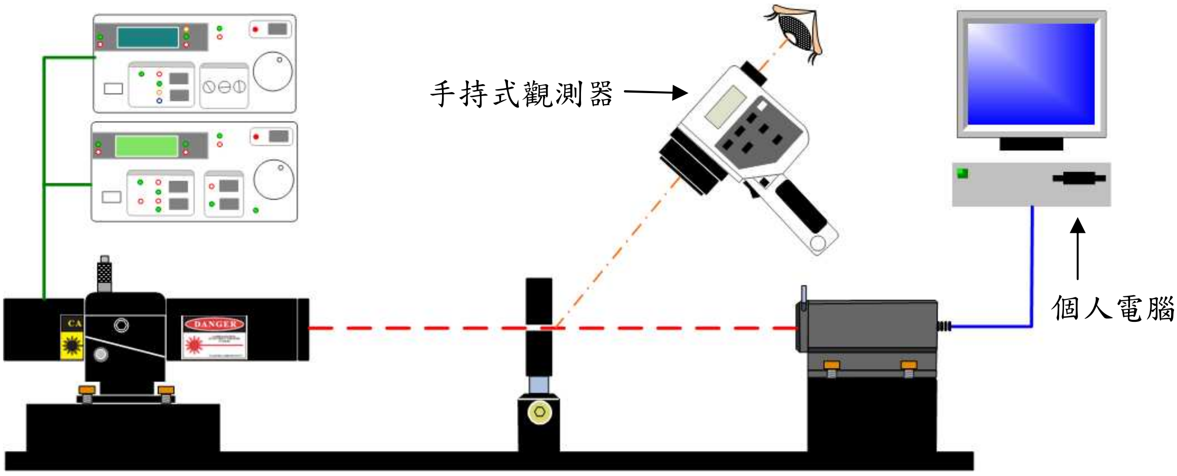
使用孔徑與透鏡雷射之量測



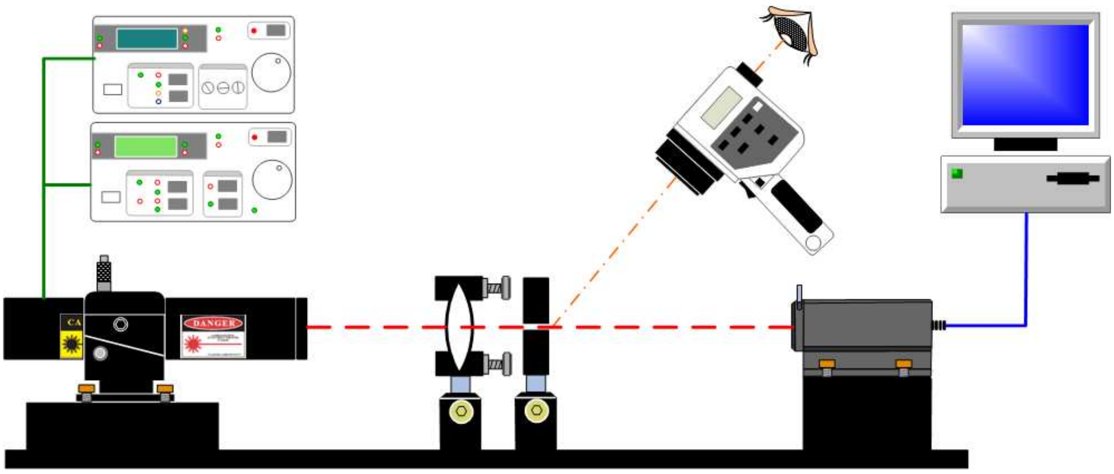
復以手持式觀測器間接觀測雷射光束，感受光束之輝度，以個人電腦分析量測數據，顯示光束之平面

與三維影像，計算 FWHM 等參數。

使用孔徑及手持式觀測器進行雷射之量測

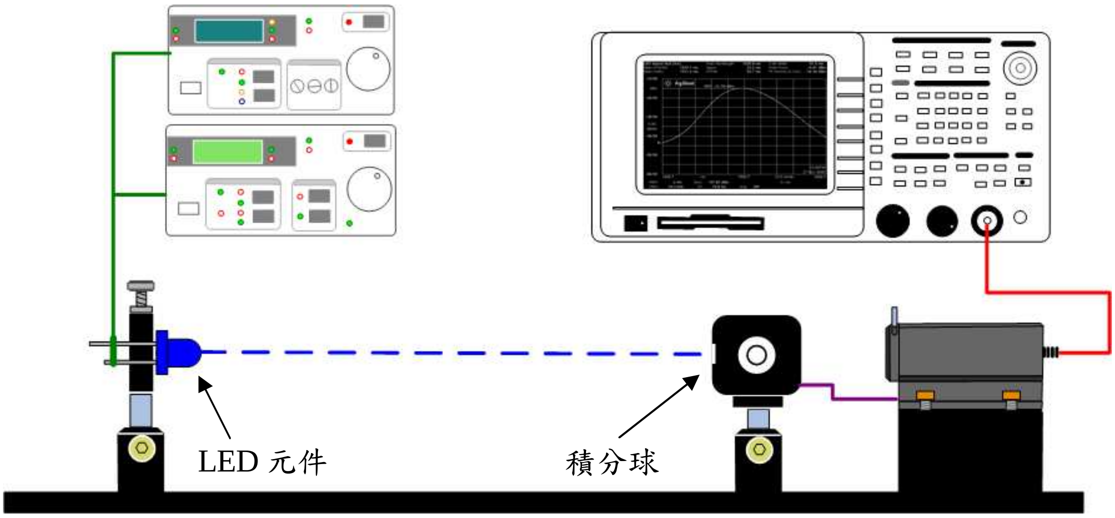


使用孔徑、透鏡與手持式觀測器進行雷射之量測

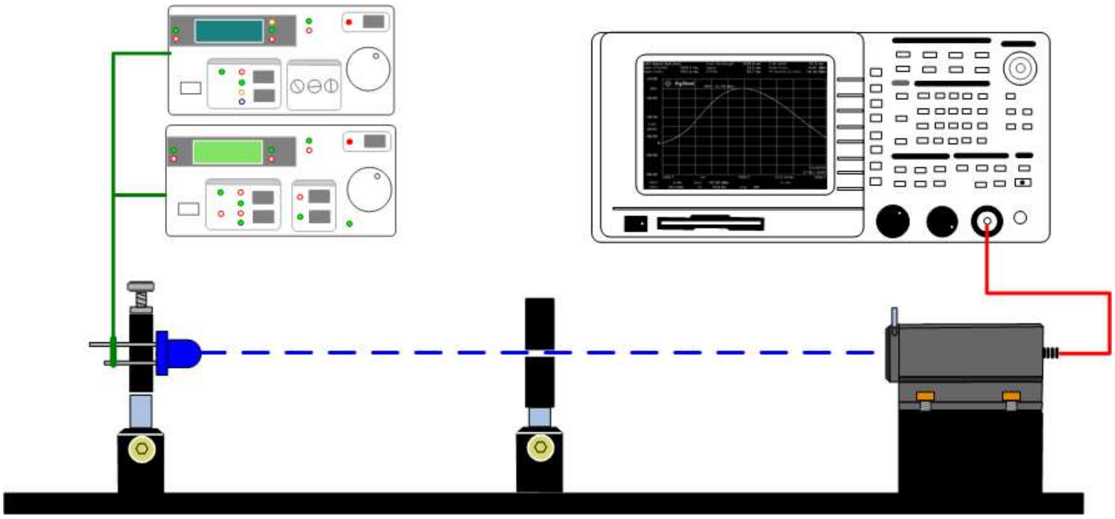


隨後進行 LED 之量測。分別以白光與藍光 LED 元件進行量測。以積分球量測光通亮及光強度等光學特性，隨後以孔徑模擬瞳孔，評估藍光對人體之危害性。

使用積分球進行 LED 之量測



使用孔徑進行 LED 之量測

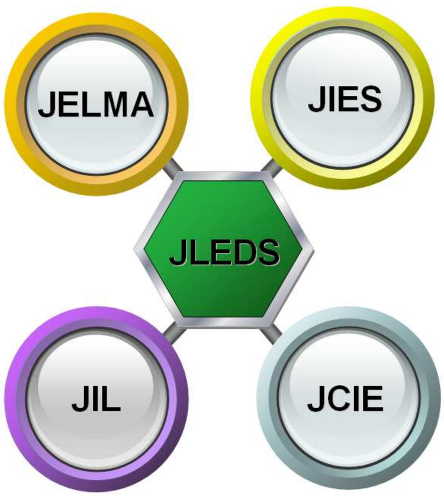


（三） 拜訪日本電球工業會

98 年 4 月 24 日由 JQA 山崎龍一副參事陪同，拜訪日本電球工業會（JELMA），與技術擔當部長赤澤幸造、專務理事武內徹二及日本照明器具工業會專務理事赤塚美津雄進行座談，會中就日本 LED 照明相關標準制定進度與計畫、產業標準整合經驗、驗證

制度等議題交換意見。

首先由武內徹二先生簡介日本電球工業會之沿革，及推動 LED 照明標準化之情形。為加速推動 LED 照明之標準化，由日本電球工業會發起，聯合日本照明學會（JIES）、日本照明委員會（JCIE）及日本照明器具工業會（JIL）共同於 2004 年 6 月 9 日成立日本 LED 照明推進協議會（JLEDS），著手制定照明用白光 LED 之測光方法，於 2004 年 11 月 12 日完成制定，復於 2006 年修訂，於 2007 年成為 JIS C 8152。在 JLEDS 成立之前，有許多組織及團體從不同之技術層次推動 LED 之應用，例如：日本電球工業會主推照明用白光 LED 模組之安全性標準，日本電機控制設備工業會（NECA）主推工業用 LED 標準，日本電子及資訊技術研究所（JEITA）主推指示及顯示用 LED 之標準，日本照明器具工業會則主推白光 LED 照明器具性能標準。



JELMA：日本電球工業會

JIES：日本照明學會

JCIE：日本照明委員會

JIL：日本照明器具工業會

在 JLEDS 成立後，統籌所有資源，積極制定與推動 LED 產品標準及量測規範，企圖繼專利策略之後，再次以 LED 標準搶佔 LED 固態照明市場先機。

除此之外，產業界也組成研發聯盟，打破單兵作戰之模式，集結技術與專利之資源，形成足以與我國、歐、美、南韓及中國大陸等國家抗衡之強大勢力，包括小系製作所、三菱電機、松下電器、日立 LIGHTING、豐田合成、USHIO、OSRAM MELCO、松下電工、NEC LIGHTING、STANLY、日亞、東芝 Lighttech、LUMILEDS LIGHTING JAPAN、ROHM 等。

武內徹二先生亦說明 JIS 近期（至 2012 年）LED 相關 JIS 制定與修訂之時程規劃，包括預定於 2011 年制定完成 JIS C8156 一般照明用 LED 光源之安全性要求（擬與 IEC 62560 調和，正由 IEC 制定中）、預定於 2012 年制定完成 JIS C8157 一般照明用 LED 光源之性能要求（調和自 IEC 62612）、預定於 2012 年制定完成 JIS C8158 一般照明用 LED 光源之產品規格（由日本自行制定，與 IEC 62560 及 IEC 62612 對應）、將於今年制定完成 JIS C8154 一般照明用 LED 模組之安全性要求（調和自 IEC 62031）及將於今年制定完成 JIS C8153 LED 模組電源控制裝置

之性能要求（調和自 IEC 62384）等。

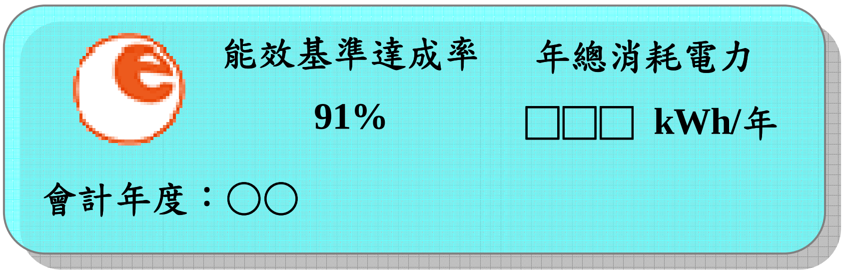
在驗證制度方面，除了在 JQA 研習期間所了解強制性之 PSE 標識及自願性之 S 標識外，日本對於節能產品尚有省能源標章（Energy Saving Label）之自願性產品驗證制度，類似我國之節能標章。日本於 1979 年第二次能源危機發生時制定省能源法（Energy Conservation Law），主要針對工廠、建築物及高耗能之器具設備，揭櫫相關節約能源措施，展開耗能器具與設備能源效率管理之行動，採取最低能源效率基準（Minimum Energy Performance Standard, MEPS）之管理模式，以淘汰一定比率之低能效產品，或基於技術及經濟可行制定最低能效基準，並規定自施行年度起，不符合規定能效基準之產品將不得進口或銷售，目前大部份國家皆採行此種能效管理方式。

1998 年日本再度修訂省能源法，將節能標竿（Top Runner）之理念納入法律條文中，即就目前商品中能效最優異者為基準，並考量未來技術之發展，訂定能源效率目標值，並要求該產品之製造商或進口商，須在規定之目標年度內達成所要求之能效基準，此係目前日本採行之能源效率管理新方式。

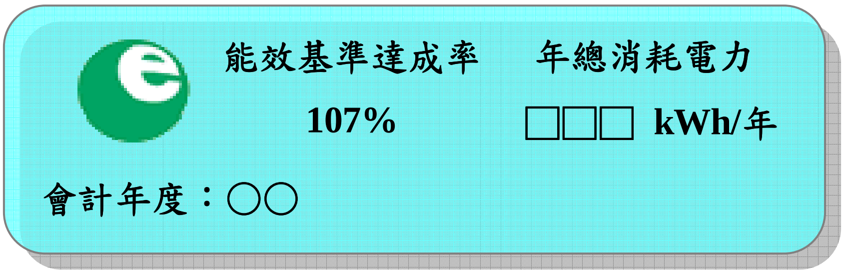
日本省能源標示制度為節能標竿推動之配套措施，目的在於使消費者了欲購買之產品是否已達到能

源效率目標值，以引導消費者選購省能產品，而政府亦可用以監督業者是否符合法規要求。日本省能源標示制度雖為自願性，惟絕大部分之業者皆配合標示。省能源標章分為橘色與綠色，橘色代表未達能源效率基準，綠色代表已達（或超過）能源效率基準，標示方式如下所示。

未達能源效率基準之標示方式



已達能源效率基準之標示方式



在光源方面，目前僅有螢光燈管一項，在 LED 普及之後，將可能納入省能源標章之範圍。

在雙方充分交換意見後，與山崎龍一、赤澤幸造、武內徹二及赤塚美津雄等人合影後離去。結束為期 10 天之出國行程。

四、 心得與建議

透過本次之行程，體認全球在 LED 製程、檢測與商品化等方面發展之趨勢，並對於 IEC 60825-1 及 IEC 62471 在量測理論與技術方面有較深刻之了解。另在 LED 實測方面，對於相關設備之配置、儀器之調校、架設、量測之程序及資料之判讀等，均建立一定之認知與能力，而在日本 LED 標準化推動與驗證制度方面亦有基本之認識。

由於本局對 LED 領域方面之技術、資訊、資料與設備等方面之投入起步較晚，爰標準制定、驗證制度及檢測技術，能師法於具有足夠經驗之日本 JQA，實為難得之寶貴經驗。日後無論在標準與檢測之業務上，必能將所獲得之經驗充分落實，有助於業務之推動。

在標準制定方面，本局在 IEC 62031（一般照明用 LED 模組之安全性要求）之制定上與日本同步，均可望在今年度完成，而在 IEC 62384（LED 模組電源控制裝置之性能要求）之制定上則領先日本，CNS 已於去年（97）公布，而日本預定在今年度始完成。另 IEC 62612（一般照明用 LED 光源之性能要求）本局正開始制定，日本則預定於 2012 年完成、IEC 62560（一般照明用 LED 光源之安全性要求）本局擬著手研擬草案，而日本預定在 2011 年完成，我國可望能領先日本。

由於光源所產生之光生物性危害已日漸受到重視，有

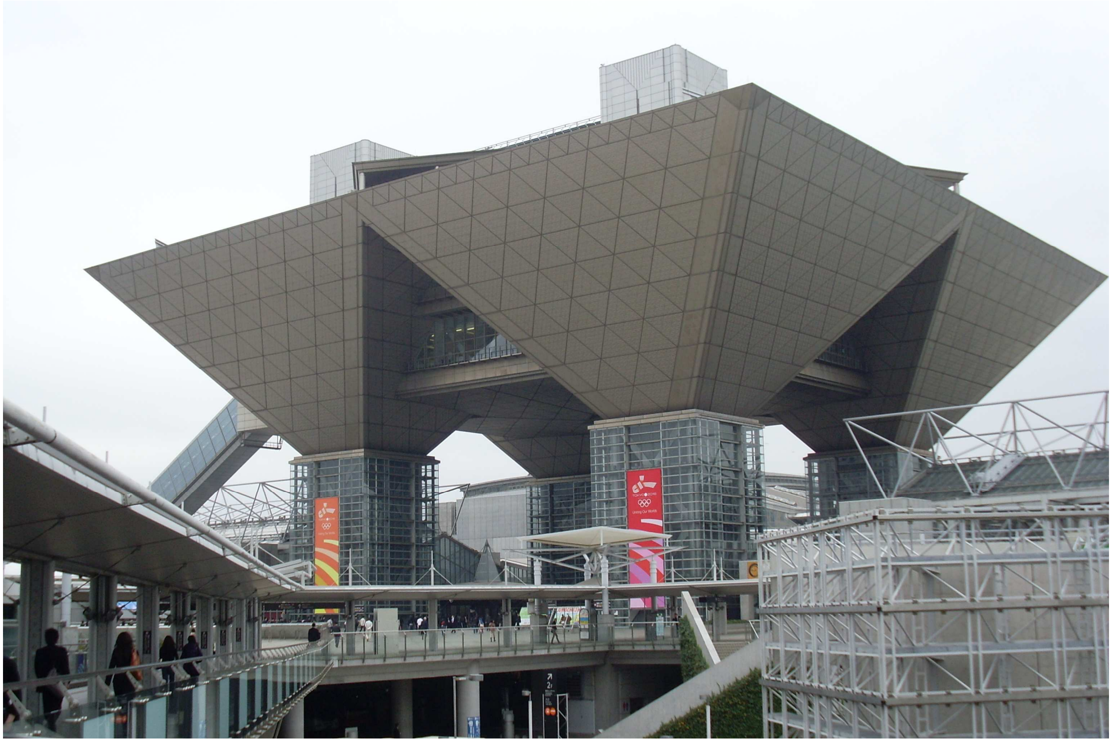
關雷射安全方面，本局已參照 IEC 60825-1 制定 CNS 15016-1「雷射產品安全－第 1 部：設備分類、要求和用戶指南」及 IEC 60825-2 制定「雷射產品安全－第 2 部：光纖通訊系統之安全性」，而光生物性評估方法則尚未制定國家標準，未來可參照 IEC 62471「Photobiological safety of lamps and lamp systems」及 IEC 62471-2「Photobiological Safety of Lamps and Lamps Systems – Part 2: Guidance on manufacturing requirements relating to non-laser optical radiation safety」（IEC 正制定中）制定 CNS，以作為相關照明類產品檢測之依據。

在光源之產品驗證方面，LED 光源雖已問世一段時間，但由於價格高昂且技術尚在發展中，普及率不高，日本對於該項產品亦未實施強制性產品驗證。未來在標準齊備、產品成熟普遍後，產品驗證之需求預料將浮現，採自願性或強制性之模式，檢測能力與能量之建立均刻不容緩，在此行之研修過程中已了解 LED 量測必要之設備，可作為檢測設備建置之參考。

在本次參訪行程中，與 JQA 及 JELMA 建立良好的溝通管道，今後不論在標準及技術資料之共享，及檢測問題研討與交流等方面，均有聯絡窗口可供聯繫，對於業務之推動可望更為順暢。

附錄一：活動照片

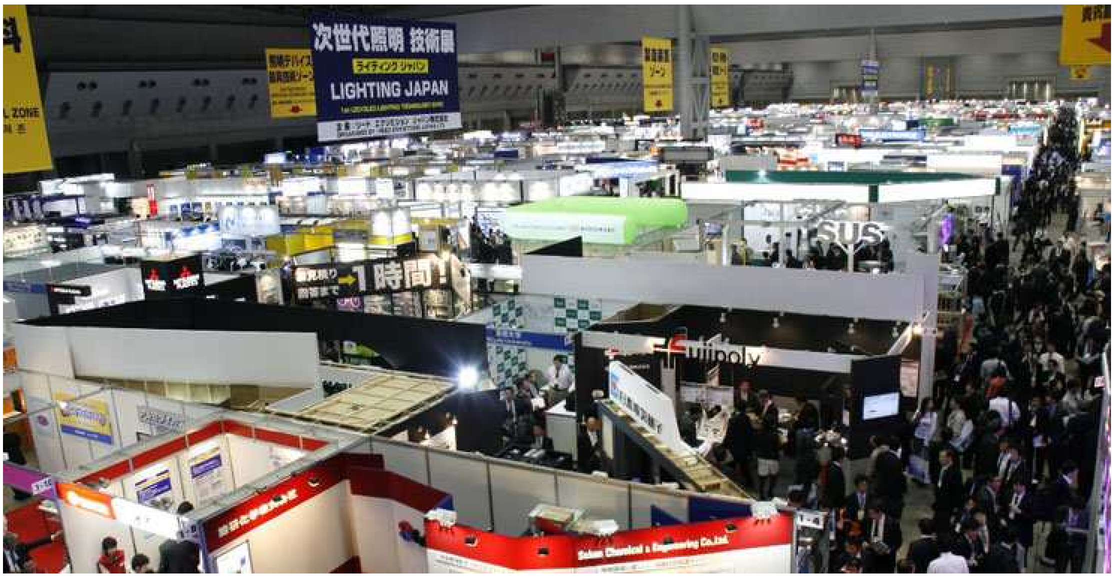
日本東京有明國際展覽中心（Tokyo Big Sight, Japan）



LIGHTING JAPAN 展覽報到處

LIGHTING JAPAN 展覽等候進場之人潮

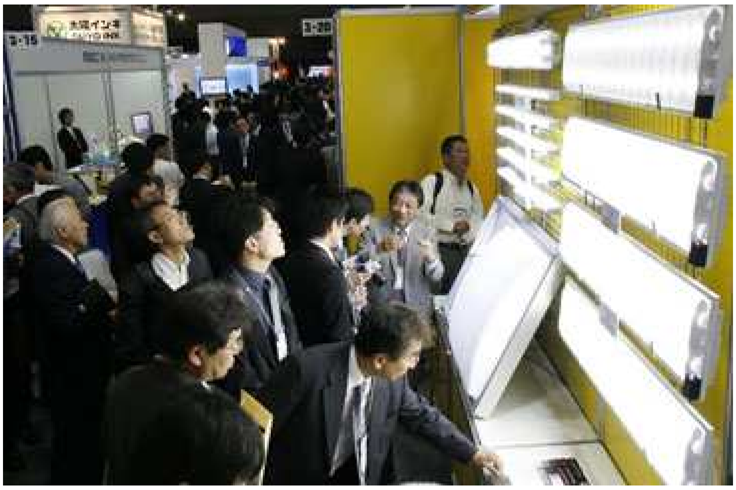
LIGHTING JAPAN 展覽會場內之盛況



LIGHTING JAPAN 展覽會場內之盛況

LIGHTING JAPAN 展覽會場內之實況

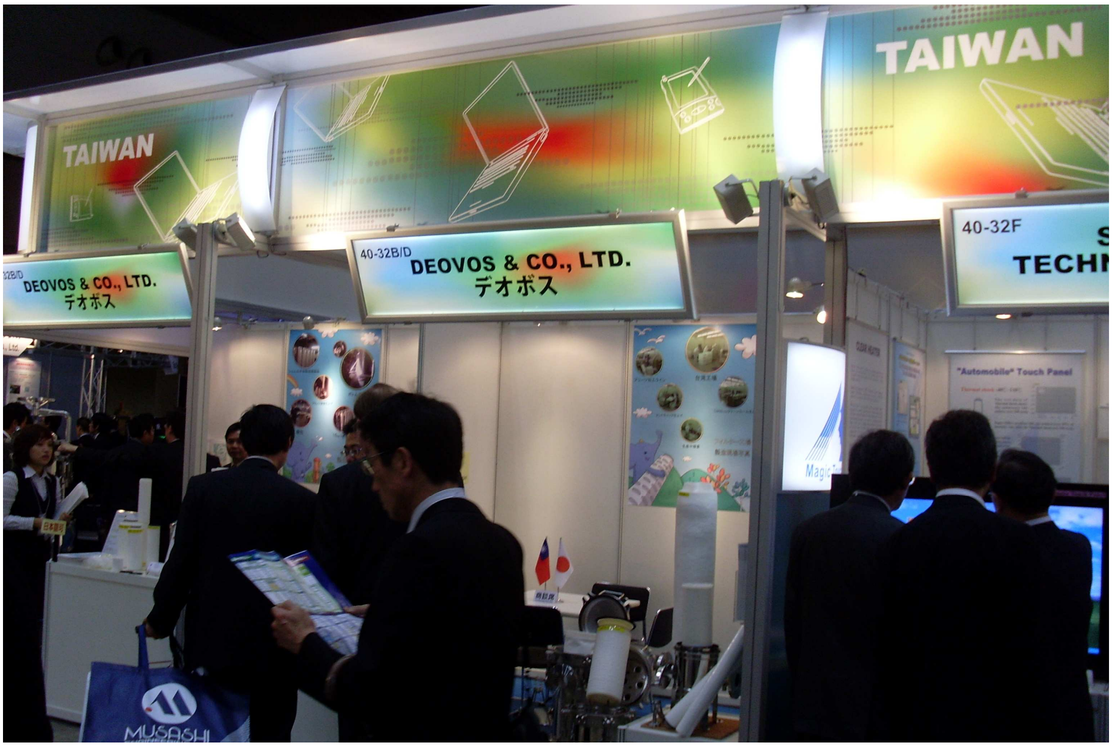
LIGHTING JAPAN 展覽會場內之實況



FINETECH JAPAN 展覽會場內之盛況

FINETECH JAPAN 展覽會場內之盛況

FINETECH JAPAN 展覽會場中之台灣展場



在 JQA 研習之情形，由立原克法工程師授課

與 JQA 技術人員合影

由 JQA 後藤智課長頒授邱技士垂興結訓證書

由 JQA 後藤智課長頒授葉技正永宏結訓證書

與日本電球工業會之人員合影

於 JQA 總部之留影

日本東京市交通號誌燈應用 LED 之情形

日本東京市戶外顯示看板應用 LED 之情形

附件1

1st LED/OLED Lighting Technology Expo
LIGHTING JAPAN

List of Exhibitors 2009

April 15th to 17th, 2009

LIGHTING JAPAN

- ABILITY TECHNOLOGY CORP. [5-24B]
- ACSES CO., LTD. [5-003]
- AISIN SEIKI CO., LTD. [7-16]
- ALPHAX CO., LTD. [10-10]
- AMA PRECISION INC. [5-24L]
- ARON EVER-GRIP LTD. [1-20]
- ASAHI SPECTRA CO., LTD. [8-22]
- ASAHI KASEI E-MATERIALS CO. [8-23]
- ASAHI KASEI E-MATERIALS CO. / NAGASE CO., LTD. [8-23]
- ASKK CO., LTD. [2-10]
- AXIA CO., LTD. [7-45]
- AYA CORP. [3-36]
- AYUMI INDUSTRY CO., LTD. [6-9]
- C.C.D. CORP. [9-8]
- C.I.KASEI CO., LTD. [3-33]
- CAL-COMP ELECTRONICS & COMMUNICATIONS CO., LTD. [5-24A]
- CAPTAIN INDUSTRIES, INC. [8-24]
- CBC CO., LTD. [4-36]
- CENTURY ELECTRONICS CO., LTD. [2-30]
- CHAINZONE TECHNOLOGY (FOSHAN) CO., LTD. [6-19]
- CHIYODA TRADING CORPORATION CO., LTD. [3-19]
- CITRA JAPAN CO., LTD. [2-34]
- CODES CO., LTD. [6-34]
- CORESEM INC. [10-19]
- CYBERNET SYSTEMS CO., LTD. [9-19]
- D&A INTERNATIONAL CORP. [5-8]
- DAICEL CHEMICAL INDUSTRIES LTD. [4-003]
- DAITO ELECTRON CO., LTD. [9-3]
- DENKI KAGAKU KOGYO KABUSHIKI KAISHA [4-22]
- DENRYO CO., LTD. [1-35]
- DUELLER CO., LTD. [1-16]
- ECOCONSORTIUM LLP [6-44]
- EDR LLC [8-9]
- ELECTRO SCIENTIFIC INDUSTRIES CO., LTD. [8-3]
- ELECTRONIC JOURNAL INC. [9-18]
- ELSTREAM CORP. [1-46]
- EME CORP. [6-7]
- ENGIS JAPAN CORP. [5-4]
- ENLUX CO., LTD. [3-34]
- ENPLAS CORP. [2-9]
- ESCHENBACH OPTIK GMBH [8-32C]
- FIKS COMMUNICATIONS CO., LTD. [7-33]
- FS TRADE [7-30]
- FUJI POLYMER INDUSTRIES CO., LTD. [2-4]
- FUJII OPTICAL CO., LTD. [9-9]
- FUJIPOLY DSEM CO., LTD. [2-23]
- FUJITEC INTERNATIONAL INC. [4-4]
- FUKUSAN CORPORARION [1-30]
- FUTURE ELECTRONICS [7-20]
- GENELITE INC. [7-38]
- GLANZ TECHNOLOGIE CO., LTD. [2-38]
- GOLDLINE USA INC. [3-35]
- GREEN TREASURES TECHNOLOGY CO., LTD. [5-24N]
- HIATEC CO., LTD. [7-30]
- HIKARI CO., LTD. [7-30]
- HIROKAWA CO. [7-30]
- HISA TOYO TEC INC. [8-29]
- HISOL INC. [9-16]
- HITACHI HIGH-TECHNOLOGIES CORP. [9-4]
- HORIBA, LTD. [10-7]
- HTL CO. JAPAN LTD. [6-3]
- IDEMITSU KOSAN CO., LTD. [1-8]
- INDUSTRIAL TECHNOLOGY RESEARCH INSTITUTE CO. [5-24D]
- INEX CORP. [1-38]
- INSTRUMENT SYSTEMS GMBH [8-20]
- ISHIZUKA ELECTRONICS CORPORATION [1-23]
- ITOCHU PLASTICS INC. [1-37]
- ITOCHU PLASTICS INC. [1-37]
- IWATANI CORP. [6-10]
- JAPAN ELECTRIC METERS INSPECTION CORPORATION [11-7]
- JAPAN ELECTRONICS TECHNICAL CO., LTD. [7-30]
- JINNOU RYUTSU CO., LTD. [7-30]
- JUKEN KOGYO CO., LTD. [1-22]
- KAGA COMPONENTS CO., LTD. [2-003]
- KANEHIRODENSHI CO., LTD. [7-33]
- KASAI SANGYO CO., LTD. [7-34]
- KAWACHIKINZOKU CO., LTD. [1-33]
- KAWAI ELECTRIC HEATER CO., LTD. [6-24]
- KAWAI OPTICS CO., LTD. [8-7]
- KAWAJUN INDUSTRY CO., LTD. [1-5]
- KEEPER TECHNOLOGY CO., LTD. [5-24H]
- KEINANDENKI CO., LTD. [7-30]
- KEISHIN CORP. [1-10]
- KENTECH CO., LTD. [7-24]
- KIKUCHI DENKOSHA [7-30]
- KISCO LTD. [3-10]
- KITAGAWA INDUSTRIES LTD. [2-24]
- KMW INC. [2-46]
- KOHA CO., LTD. [4-29]
- KOMICO LTD. [7-8]
- KOWA CO., LTD. [3-38]
- KYOKKO TRADING CO., LTD. [9-7]
- LED LINEAR GMBH [8-32B]
- LEDLINK OPTICS INC. [5-24I]
- LIVERAGE TECHNOLOGY INC. [5-24C]
- LTS(LASER TOTAL SOLUTION) CO., LTD. [7-7]
- LUMIOTEC INC. [4-45]
- MARUBUN CORP. [7-002]
- MEISHO CO., LTD. [7-37]
- MICO MST LTD. [7-8]
- MINAKUCHI LIGHTEC CO., LTD. [3-33]
- MITSUBISHI ENGINEERING-PLASTICS CORP. [1-17]
- MITSUBISHI PLASTICS INC. [2-16]
- MITUKURA SANGYOU CO., LTD. [7-30]
- MIWA MFG CO., LTD. [7-3]
- MOMO ALLIANCE CO., LTD. [2-37]
- MONDO ARC MAGAZINE LTD. [5-21]
- MUSASHI ENGINEERING, INC. [6-4]
- NABESEI CO., LTD. [3-3]
- NARASAKI SANGYO CO., LTD. [6-30]
- NATIONAL SEMICONDUCTOR JAPAN LTD. [3-20]
- NEOPTO / CARRY BEAM CO., LTD CO., LTD. [5-24G]
- NIHON CERATEC CO., LTD. [3-002]
- NIIGATA CO., LTD. [1-27]
- NIIGATA UNIVERSITY [2-8]
- NIKON CORPORATION [9-21]
- NIPPON ELECTRIC GLASS CO., LTD. [2-3]
- NIPPON ENGINEERING INDUSTRY & SERVICE CO., LTD. [6-002]
- NIPPON FILCON CO., LTD. [3-15]
- NIPPON RIKA KOGYOSHO CO., LTD. [3-24]
- NITTETSU MINING CO., LTD. [2-21]
- NITTOH KOGAKU K.K. [5-23]
- NOVALED AG [8-32H]
- OH'TEC ELECTRONICS INC. [11-3]

- MINAKUCHI LIGHTEC CO., LTD. [3-33]
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- NOVALED AG [8-32H]
- OH'TEC ELECTRONICS INC. [11-3]
- OPTIS ASIA & PACIFIC K.K. [10-9]
- OPTO DESIGN, INC. [2-29]
- OPTOSIRIUS CORP. [11-9]
- OPTRONICS CO., LTD. [2-20]
- OSAKA ECOLIFE [7-34]
- OSRAM GMBH [8-32E]
- OSRAM OPTO SEMICONDUCTORS [8-32D]
- OTSUKA ELECTRONICS CO., LTD. [8-4]
- O-WELL CORP. [3-45]
- PANASONIC FACTORY SOLUTIONS CO., LTD. [7-10]
- PANASONIC SEMICONDUCTOR OPTO DEVICES CO., LTD. [7-33]
- PHOTONICS INDUSTRY & TECHNOLOGY DEVELOPMENT ASSOCIATION [1-31]
- PIONEER FA CORP. [6-16]
- PLANSEE JAPAN LTD. [3-29]
- PRINCETON TECHNOLOGY CORP. [5-24K]
- RAPYUTA INTERNATIONAL CO., LTD. [1-36]
- REED BUSINESS INFORMATION JAPAN K.K. [10-15]
- RIKEI CORP. [1-11]
- RISOH KEISOKU K.K. [10-8]
- SAIJO INX CO., LTD. [1-15]
- SAKAMOTO DENKI SETSUBI CO., LTD. [7-30]
- SAN-EI KAGAKU CO., LTD. [4-23]
- SANGYO TIMES, INC. [2-22]
- SANIL TECH CO., LTD. [5-33]
- SDI ELECTRONICS JAPAN CO., LTD. [3-15]
- SEISHIN TRADING CO., LTD. [8-16]
- SERIC LTD. [2-19]
- SHIMANE ELECTRONICS IMAFUKU WORKS CO., LTD. [7-24]
- SHINAGAWA SHOKO CO., LTD. [8-19]
- SHIN'EI CO., LTD. [8-37]
- SHINTOKU CO., LTD. [8-33]
- SHINWA CO., LTD. [5-16]
- SHOWA PRECISION TOOLS CO., LTD. [3-19]
- SIIX CORP. [7-29]
- SK CO., LTD. [3-9]
- SMT CO., LTD. [1-16]
- SNU PRECISION CO., LTD. [7-4]
- SOKEN CHEMICAL & ENGINEERING CO., LTD. [1-4]
- SOLIDLITE CORP. [2-33]
- SQ CORPORATION LTD. [3-36]
- ST WIDE CO., LTD. [1-36]
- SUMIKA ACRYL CO., LTD. [4-19]
- SUMITA OPTICAL GLASS,INC. INC. [1-1]
- SUMITOMO BAKELITE CO., LTD. [4-12]
- SUMITOMO CHEMICAL CO., LTD. [4-19]
- SUN-EH ELECTRIC CO., LTD. [1-7]
- SUPER WAVE CORPORATION CORP. [3-33]
- SUS CORP. [3-4]
- SYK CO., LTD. [3-31]
- SYSTEMHOUSE SUNRISE INC. [10-4]
- TAIWAN LIGHTING FIXTURE EXPORT ASSOCIATION [5-24F]
- TAIYO INK MFG. CO., LTD. [3-23]
- TAMURA CO. [4-29]
- TANAKA KIHAN CO., LTD. [8-8]
- TANAKA MANUFACTURING CO., LTD. [5-29]
- TDC CORP. [1-13]
- TECHNO ALPHA CO., LTD. [1-002]
- TEIJIN LTD. [4-30]
- TEIJIN CHEMICALS LTD. [4-30]
- TEIJIN DUPONT FILMS JAPAN LIMITED LTD. [4-30]
- TEIYO CO., LTD. [4-30]
- TEKLUX CO., LTD. [6-44]
- TEKNOLOGUE CO., LTD. [9-15]
- TES ELECTRICAL ELECTRONIC CORP. [5-24E]
- THE FURUKAWA ELECTRIC CO., LTD. [1-24]
- THE NIKKAN KOGYO SHIMBUN LTD. [6-20]
- TING CHIN INDUSTRIAL CO., LTD. [5-24M]
- TOKKI CORP. [7-19]
- TOPCON CORPORATION [8-003]
- TOPCON TECHNOHOUSE CORPORATION [8-003]
- TOSHIBA MACHINE CO., LTD. [7-002]
- TOSHIN ELECTRIC CO., LTD. [6-38]
- TOWA CORPORATION [6-003]
- TOYOTA TSUSHO CORP. [1-16]
- TRIGEM COMPUTER INC. [3-25]
- UBI SANUP RESEARCH CO., LTD. [1-9]
- UHT CORP. [6-10]
- UL JAPAN, INC. [8-10]
- VISION PSYTEC CO., LTD. [8-8]
- WAFER WORKS OPTRONICS CORP. [5-24J]
- WITHLIGHT [7-34]
- YAMASHITA MATERIALS CORP. [2-15]
- YAMATO MATERIAL CO., LTD. [7-23]
- YOUNG LIGHTING TECHNOLOGY INC. [3-37]
- YOUTEC CO., LTD. [5-10]
- YUASA ELECTRONICS CO., LTD. [9-10]

*name of manufacturers are partly provided.

FINETECH JAPAN

- TEIJIN CHEMICALS LTD. *[4-30]*
- TEIJIN DUPONT FILMS JAPAN LIMITED LTD. *[4-30]*
- TEIYO CO., LTD. *[4-30]*
- TEKLUX CO., LTD. *[6-44]*
- TEKNOLOGUE CO., LTD. *[9-15]*
- TES ELECTRICAL ELECTRONIC CORP. *[5-24E]*
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- WAFER WORKS OPTRONICS CORP. *[5-24J]*
- WITHLIGHT *[1-34]*
- YAMASHITA MATERIALS CORP. *[2-15]*
- YAMATO MATERIAL CO., LTD. *[7-23]*
- YOUNG LIGHTING TECHNOLOGY INC. *[3-37]*
- YOUTEC CO., LTD. *[5-10]*
- YUASA ELECTRONICS CO., LTD. *[9-10]*

*name of manufacturers are partly provided.

FINETECH JAPAN

- A&D COMPANY,LIMITED *[32-24]*
- ACROSENSE TECHNOLOGY CORP. *[40-32C]*
- ACT ELECTRONICS CORP. *[31-9]*
- AD SCIENCE CO., LTD. *[32-8]*
- ADEKA CORP. *[37-3]*
- ADP ENGINEERING CO., LTD. *[11-30]*
- ADVANTEC TOYO KAISHA, LTD. *[21-30]*
- AIKOKU ALPHA CORP. *[13-9]*
- AIR SYSTEM ENTERPRISE CO., LTD. *[20-16]*
- AIR WATER INC. *[20-9]*
- AIRSYSTEM ENTERPRISE & KANEMATSU TEXTILE CORPORATION CO., LTD. *[20-16]*
- AIXTRON AG *[8-32G]*
- AKEBONO MACHINE INDUSTRIES CO., LTD. *[23-46]*
- ALU CORP. *[40-13]*
- ANRITSU PRECISION CO., LTD. *[31-22]*
- ANTON PAAR JAPAN K.K. *[32-10]*
- AOMORI PREFECTURAL GOVERNMENT *[10-34]*
- AOMORI SUPPORT CENTER FOR INDUSTRIAL PROMOTION *[10-34]*
- AOV CO., LTD. *[17-33]*
- APISTE GMBH *[22-9]*
- APPLIED VACUUM COATING TECHNOLOGIES CO., LTD. *[40-32N]*
- ARCO INFOCOMM INC. *[34-10]*
- ARLUMI MACHINE CO., LTD. *[40-32A]*
- ASAHI GLASS CO., LTD. *[40-4]*
- ASAHI KASEI EIC SOLUTIONS CORP. *[15-24]*
- ASAHI KASEI FIBERS CORPORATION *[20-23]*
- ASHIZAWA FINETECH LTD. *[34-24]*
- ASONE CORP. *[23-29]*
- ASTRODESIGN INC. *[32-30]*
- ATEC CO., LTD. *[13-15]*
- AUDIO-TECHNICA CORP. *[23-35]*
- AUQ CO., LTD. *[25-30]*
- BELLMATIC LTD. *[26-29]*
- BEX INTER-CORPORATION LTD. *[42-11]*
- BN TECHNOLOGY CORP. *[32-22]*
- BNL JAPAN INC. *[12-7]*
- BOSCH REXROTH CORP. *[19-46]*
- BRIGHT CO., LTD. *[11-22]*
- BRUSHBANK CO. *[14-30H]*
- C SUN MFG. LTD. *[18-26]*
- CACO CHEMICAL INC. *[18-33]*
- CBC CO., LTD. *[32-12]*
- CHIKUMA SEIKI CO., LTD. *[28-23]*
- CHISSO FILTER CO., LTD. *[38-4]*
- CHIYODA KOGYO CO., LTD. *[40-10]*
- CHOSHU INDUSTRY CO., LTD. *[10-30]*
- CHROMA ATE INC. *[31-38]*
- CHUGAI RO CO., LTD. *[10-24]*
- CHUO CUTTER CO., LTD. *[22-8]*
- CHUO ELECTRIC WORKS LTD. *[24-16]*
- CLEAN TECHNOLOGY CO., LTD. *[13-19]*
- CLEAN VALVE CO., LTD. *[19-7]*
- CLIMB PRODUCTS CO., LTD. *[11-19]*
- COGNEX K.K. *[30-18]*
- COHERENT JAPAN INC. *[18-30]*
- CREAPHYS GMBH *[8-32F]*
- CSTEC CORP. *[25-8]*
- CYBER LASER INC. *[18-16]*
- CYBERNET SYSTEMS CO., LTD. *[33-29]*
- DAELIM CORP. *[34-18]*
- DAICO THERMOTEC CO., LTD. *[19-002]*
- DAINICHI SHOJI K.K. *[9-24]*
- DAINICHI TRADING CO., LTD. *[22-38]*
- DEMPA PUBLICATIONS, INC. INC. *[28-26]*
- DEOVOS& CO., LTD. *[40-32B]*
- DIGITAL TECHNOLOGY *[36-31]*

- ASHIZAWA FINETECH LTD. [34-24]
- ASONE CORP. [23-29]
- ASTRODESIGN INC. [32-30]
- ATEC CO., LTD. [13-15]
- AUDIO-TECHNICA CORP. [23-35]
- AUQ CO., LTD. [25-30]
- BELLMATIC LTD. [26-29]
- BEX INTER-CORPORATION LTD. [42-11]
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- DAINICHI SHOJI K.K. [9-24]
- DAINICHI TRADING CO., LTD. [22-38]
- DEMPA PUBLICATIONS, INC. INC. [28-26]
- DEOVOS& CO., LTD. [40-32B]
- DIGITAL TECHNOLOGY [36-31]
- DISPLAYBANK CO., LTD. [35-31]
- DISPLAYSEARCH [41-21]
- DKSH JAPAN K.K. [35-11]
- DM CARD JAPAN CO., LTD. [25-34]
- DONGGUAN SUOREC ELECTRONIC MATERIAL CO., LTD. [20-30]
- DR TECHNET CO., LTD. [38-29]
- DR. SCHENK JAPAN CO., LTD. [29-17]
- E SQUARE CO., LTD. [17-15]
- E.C.CHEMICAL CO., LTD. [20-9]
- E.H.C CO., LTD. [12-24]
- E.X. PRESS CO., LTD. [32-31]
- EASTERN ELECTRONICS INDUSTRIES CO., LTD. [29-44]
- EBA JAPAN CO., LTD. [31-21]
- EDR, LLC [35-35]
- EELY-ECW TECHNOLOGY LTD [39-36]
- EFUN TECHNOLOGY CO., LTD. [37-24]
- EIT CO., LTD. [41-18]
- ELECTRONIC JOURNAL INC. [28-15]
- ENGINEERING SYSTEM CO., LTD. [36-38]
- ESCHENBACH OPTIK GMBH [8-32C]
- EVONIK DEGUSSA GMBH [38-21]
- EYE GRAPHICS CO., LTD. [17-29]
- FEBACS CO., LTD. [11-4]
- FEC CORP. [11-34]
- FILMETRICS JAPAN INC. [28-18]
- FISCHER INSTRUMENTS K.K. [28-31]
- FORESIGHT CO., LTD. [39-4]
- FOUNDATION FOR PROMOTION OF MATERIAL SCIENCE AND TECHNOLOGY OF JAPAN [32-35]
- FREEBEAR CORP. [14-9]
- FUJI TEKKO CO., LTD. [24-34]
- FUJIFILM GRAPHIC SYSTEMS CO., LTD. [18-8]
- FUJIKURA KASEI CO., LTD. [40-29]
- FUJIMORI KOGYO CO., LTD. [37-18]
- FUJISANKEI BUSINESS I [12-19]
- FUJISHOKO MACHINERY CO., LTD. [24-003]
- FUKUDA CORPORATION [31-24]
- FUTAMURA CHEMICAL CO., LTD. [40-22]
- FUTEC INC. [28-28]
- GEOMATEC CO., LTD. [37-29]
- GICHO PUBLISHING & ADVERTISING CO., LTD. [34-30]
- GOLDWIN INC. [22-30]
- GS YUASA POWER SUPPLY LTD. [26-15]
- H.IKEUCHI.& CO., LTD. [21-16]
- HAKUTO CO., LTD. [15-003]
- HAMAMATSU METRIX CO., LTD. [28-9]
- HAMAMATSU PHOTONICS K.K. [29-7]
- HANGZHOU COBETTER FILTRATION EQUIPMENT/CHIYODA TRADING CO., LTD. [35-36]
- HARADA CORP. [21-15]

- E.C.CHEMICAL CO., LTD. [20-9]
- E.H.C CO., LTD. [12-24]
- E.X. PRESS CO., LTD. [32-31]
- EASTERN ELECTRONICS INDUSTRIES CO., LTD. [29-44]
- EBA JAPAN CO., LTD. [31-21]
- EDR, LLC [35-35]
- EELY-ECW TECHNOLOGY LTD [39-36]
- EFUN TECHNOLOGY CO., LTD. [37-24]
- EIT CO., LTD. [41-18]
- ELECTRONIC JOURNAL INC. [28-15]
- ENGINEERING SYSTEM CO., LTD. [36-38]
- ESCHENBACH OPTIK GMBH [8-32C]
- EVONIK DEGUSSA GMBH [38-21]
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- FEBACS CO., LTD. [11-4]
- FEC CORP. [11-34]
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- GEOMATEC CO., LTD. [37-29]
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- GOLDWIN INC. [22-30]
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- HAMAMATSU PHOTONICS K.K. [29-7]
- HANGZHOU COBETTER FILTRATION EQUIPMENT/CHIYODA TRADING CO., LTD. [35-36]
- HARADA CORP. [21-15]
- HEIAN CORPORATION CO., LTD. [19-30]
- HERAEUS K.K. [19-19]
- HIGHTEC SYSTEMS CORP. [9-46]
- HI-LAND CO., LTD. [28-003]
- HIROSHIMA PREFECTURAL INSTITUTE OF INDUSTRIAL SCIENCE AND TECHNOLOGY [34-20]
- HITACHI HIGH-TECHNOLOGIES CO. [32-17]
- HITACHI ZOSEN CORP. [11-38]
- HIWIN CORP. [18-4]
- HOYA CANDEO OPTRONICS K.K. [31-003]
- HUGLE ELECTRONICS INC. [23-24]
- I SYSTEM CORPORATION [31-30]
- ICHIA TECHNOLOGIES, LTD. [40-32K]
- IGUCHI KIKO CO., LTD. [11-16]
- IGUS K.K. [17-8]
- IMPREX INC. [40-002]
- INCOM CO., LTD. [18-19]
- INOUE KINZOKU KOGYO CO., LTD. [24-4]
- IRIE CORP. [28-27]
- IRIE KOKEN CO., LTD. [16-21]
- ISEL CO., LTD. [23-002]
- ISHII HYOKI CO., LTD. [10-29]
- ISRA SURFACE VISION [8-32K]
- ITO CORP. [20-15]
- ITOCHU SANKI CORP. [15-30]
- ITOCHU SANKI CO., LTD. [24-30]
- ITOH ROKU INC. CO., LTD. [33-4]
- IWASAKI ELECTRIC CO., LTD. [25-33]
- IWASHITA ENGINEERING INC. [15-22]
- J. A. WOOLLAM JAPAN CORP. [31-35]
- JAPAN AIR GASES CO. AIR LIQUIDE JAPAN LTD. [22-16]
- JAPAN KANIGEN CO., LTD. [25-30]
- JAPAN SCIENCE ENGINEERING CO., LTD. [16-8]
- JAPAN TECHNOLOGY SYSTEM CORP. [23-9]
- JASCO INTERNATIONAL CO., LTD. [33-23]
- JFE TECHNORESEARCH CORP. [30-22]
- JINAN TMMT STONE CO., LTD. [33-7]
- JOYO ENGINEERING CO., LTD. [15-4]
- JPTEC CO., LTD. [9-38]

- ITO CORP. [20-15]
- ITOCHU SANKI CORP. [15-30]
- ITOCHU SANKI CO., LTD. [24-30]
- ITOH ROKU INC. CO., LTD. [33-4]
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- JAPAN KANIGEN CO., LTD. [25-30]
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- JAPAN TECHNOLOGY SYSTEM CORP. [23-9]
- JASCO INTERNATIONAL CO., LTD. [33-23]
- JFE TECHNORESEARCH CORP. [30-22]
- JINAN TMMT STONE CO., LTD. [33-7]
- JOYO ENGINEERING CO., LTD. [15-4]
- JPTEC CO., LTD. [9-38]
- JUNKOSHA INC. [33-12]
- KAMATA INDUSTRY CO., LTD. [23-30]
- KANEMATSU CORP. [10-29]
- KANSAI KAKOKI SHOKAI LTD. [23-22]
- KANTO CHEMICAL CO.,INC. [37-11]
- KANTO KOUKI CO., LTD. [25-30]
- KASUGADENKI, INC. [22-15]
- KAWAKAMI IRON WORKS CO., LTD. [14-16]
- KAWATA MFG. CO., LTD. [23-10]
- KB SEIREN LTD. [21-21]
- KEN AUTOMATION INC. [28-11]
- KEYENCE CO. [32-44]
- KIKUKAWA IRON WORKS, INC. [14-003]
- KIMOTO CO., LTD. [38-34]
- KISCO LTD. [33-30]
- KITO CORP. [18-38]
- KOBAYASHI ENGINEERING WORKS, LTD. [26-4]
- KOBE STEEL, LTD. [21-002]
- KOBELCO RESEARCH INSTITUTE, INC. [40-001]
- KOGYOCHOSAKAI PUBLISHING CO., LTD. [17-20]
- KOKEN LTD. [21-4]
- KONICA MINOLTA SENSING, INC. [32-3]
- KOREA DISPLAY INDUSTRY ASSOCIATION [14-30A]
- KOREA LASER TECH CO., LTD. [40-33]
- KOTRA (KOREA TRADE-INVESTMENT PROMOTION AGENCY) [14-30A]
- KOYOSHOKO CO., LTD. [17-24]
- KUBOTEK CORP. [30-44]
- KURE GRINDING WHEEL CO., LTD. [13-30]
- KUREHA ELASTOMER CO., LTD. [40-35]
- KURIMOTO PLASTICS CO., LTD. [36-24]
- KURITA WATER INDUSTRIES LTD. [10-16]
- KYODO GIKEN CHEMICAL CO., LTD. [40-17]
- KYOEI ELECTRIC CO., LTD. [24-21]
- KYOEI PRINT GIKEN CO., LTD. [25-38]
- KYORITSU PHYSICAL DISTRIBUTION SYSTEM CO., LTD. [33-36]
- KYOSIN ENGINEERING CORP. [14-10]
- LABO CO., LTD. [25-20]
- LANDESMESSE STUTTGART GMBH
- LANTECHNICAL SERVICE CO., LTD. [10-46]
- LASERCK CORP. [21-001]
- LED LINEAR GMBH [8-32B]
- LEXER MATRIX INC. [36-003]
- LINKSTAR JAPAN CO., LTD. [15-46]
- LINTEC CORP. [37-44]
- M. D. EXCIMER INC. [11-20]
- MACTECH CORPORATION [40-32G]
- MAEDA KOSEN CO., LTD. [22-20]
- MARUBENI TECHNO-SYSTEMS CORP. [24-4]
- MARUI GALVANIZING CO., LTD. [16-24]
- MATSUNAMI GLASS IND., LTD. [34-4]
- MCC CO., LTD. [20-10]
- MCK CO., LTD. [36-30]
- MEC CO., LTD. [29-24]
- MECHATROLINK MEMBERS ASSOCIATION [14-29]
- MEIRITSU SEIKI CO., LTD. [13-16]
- MEIRYO TECHNICA CORP. [28-1]
- MEIWA RUBBER CO., LTD. [20-46]
- MEK ENGINEERING CORP. & GM ENGINEERING CO., LTD. [32-7]
- MELTEC CORP. [36-11]
- MICRO INSPECTION INC. [14-30B]

- KURITA WATER INDUSTRIES LTD. [10-16]
- KYODO GIKEN CHEMICAL CO., LTD. [40-17]
- KYOEI ELECTRIC CO., LTD. [24-21]
- KYOEI PRINT GIKEN CO., LTD. [25-38]
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- LANTECHNICAL SERVICE CO., LTD. [10-46]
- LASERCK CORP. [21-001]
- LED LINEAR GMBH [8-32B]
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- MEIRYO TECHNICA CORP. [28-1]
- MEIWA RUBBER CO., LTD. [20-46]
- MEK ENGINEERING CORP. & GM ENGINEERING CO., LTD. [32-7]
- MELTEC CORP. [36-11]
- MICRO INSPECTION INC. [14-30B]
- MICRO TECHNOLOGY CO., LTD. [37-003]
- MICROCIRCUS CO., LTD. [39-29]
- MICRONIC JAPAN K.K. [16-22]
- MIDORI ANZEN CO., LTD. [23-38]
- MIKADO TRADING CO., LTD. [22-001]
- MIKI PULLEY CO., LTD. [13-38]
- MINATO ELECTRONIC INC. [41-24]
- MITSUBISHI CHEMICAL CORP. [34-43]
- MITSUBISHI CHEMICAL ENGINEERING CORP. [34-43]
- MITSUBISHI PLASTICS INC. [39-12]
- MITSUBOSHI DIAMOND INDUSTRIAL CO., LTD. [14-46]
- MITSUBOSHI DIAMONDO INDUSTRIAL CO., LTD. [40-44]
- MITSUHASHI CORP. [20-3]
- MITSUI CHEMICAL ANALYSIS & CONSULTING SERVICE INC. [32-13]
- MITSUWA FRONTECH CORP. [33-9]
- MITUTOYO CORP. [28-4]
- MORITEX CORP. [32-001]
- MOTION CONTROL CO., LTD. [34-9]
- MURAKAMI COLOR RESEARCH LABORATORY [32-25]
- MUSASHI ENGINEERING, INC. [15-36]
- MUSASHINO ENGINEERING CO., LTD. [12-34]
- MUTTO OPTRONICS (SUZHOU) CO., LTD. [40-32E]
- NABEYA BI-TECH CO., LTD. [17-16]
- NAGAOKA SANGYOU CO., LTD. [37-17]
- NAGASE & CO., LTD. [30-10]
- NAGASE & CO., LTD. [25-36]
- NAGASE & CO.,LTD. [25-36]
- NAGASE INTEGREX CO., LTD. [12-001]
- NAKAMURA MFG CO., LTD. [30-29]
- NANO TEM CO., LTD. [13-36]
- NEO TECHNOLOGY INC. [36-29]
- NEOVIEW KOLON CO., LTD. [35-30]
- NEW WAY AIR BEARINGS INC. [31-24]
- NIC AUTOTEC, INC. [22-46]
- NICHIEI KAKOH CO., LTD. [37-30]
- NIDEK CO., LTD. [37-4]
- NIHON MICRO COATING CO., LTD. [39-30]
- NIHON SIBERHEGNER K.K. [26-28]
- NIKON CORP. [17-35]
- NIKON INSTECH CO., LTD. [30-003]
- NIPPA CORP. [36-003]
- NIPPON BEARING CO., LTD. [15-16]
- NIPPON DENSHOKU INDUSTRIES CO., LTD. [32-18]
- NIPPON FUSSO CO., LTD. [17-4]
- NIPPON FUSSO CO., LTD. [35-3]
- NIPPON PAINT CO., LTD. [40-3]
- NIPPON PAPER CHEMICALS CO., LTD. [39-24]
- NIPPON PAPER CRECIA CO., LTD. [22-24]
- NIPPON PETRO CO., LTD. [38-24]
- NIPPON ROPER GMBH [29-3]
- NIPPON SOLVAY K.K. [40-8]
- NIPPONTERPENE CHEMICALS, INC. [39-11]
- NIRECO CORP. [29-36]
- NISSAN CHEMICAL INDUSTRIES LTD. [35-43]
- NODASCREEN CO., LTD. [36-12]
- NOMURA TRADING CO., LTD. [37-24]

- NAKAMURA MFG CO., LTD. *[30-29]*
- NEO TECHNOLOGY INC. *[36-29]*
- NEW WAY AIR BEARINGS INC. *[31-24]*
- NICHIEI KAKOH CO., LTD. *[37-30]*
- NIHON MICRO COATING CO., LTD. *[39-30]*
- NIKON CORP. *[17-35]*
- NIPPA CORP. *[36-003]*
- NIPPON DENSHOKU INDUSTRIES CO., LTD. *[32-18]*
- NIPPON FUSSO CO., LTD. *[35-3]*
- NIPPON PAPER CHEMICALS CO., LTD. *[39-24]*
- NIPPON PETRO CO., LTD. *[38-24]*
- NIPPON SOLVAY K.K. *[40-8]*
- NIRECO CORP. *[29-36]*
- NODASCREEN CO., LTD. *[36-12]*
- NORITAKE CO., LTD. *[26-8]*
- OGIC TECHNOLOGIES CO LTD. *[23-15]*
- OHKAWA & CO., LTD. *[9-24]*
- OIKE FINE COATING, INC. *[36-003]*
- OKD CO., LTD. *[19-29]*
- OMRON CORP. *[24-33]*
- OPTO SCIENCE INC. *[29-23]*
- OPTRONICS CO., LTD. *[39-9]*
- OSADA CORP. *[22-29]*
- OSRAM GMBH *[8-32E]*
- OTSUKA ELECTRONICS CO., LTD. *[30-30]*
- PAIONIA FURYOKUKI CO., LTD. *[20-4]*
- PEOPLE & TECHNOLOGY INC. *[14-30F]*
- PI-JAPAN CO., LTD. *[19-8]*
- PRECITEC JAPAN LTD. *[31-18]*
- PRIME NET INC. *[13-4]*
- RAYDENT INDUSTRIAL CO., LTD. *[19-4]*
- RAYTRONICS CORP. *[31-10]*
- RESEARCH LABORATORY OF PLASTICS TECHNOLOGY CO., LTD. *[25-22]*
- RION CO., LTD. *[21-10]*
- RYOKA SYSTEMS INC. *[34-43]*
- SAES GETTERS JAPAN CO., LTD. *[34-23]*
- SAKAI MANUFACTURING CO., LTD. *[12-20]*
- SANGYO TIMES , INC. *[32-21]*
- SANKI ENGINEERING CO., LTD. *[21-38]*
- SANKYO SEISAKUSHO CO. *[19-9]*
- SANWA COKEN *[22-10]*
- SBB TECH CO., LTD. *[13-10]*
- SCHOTT NIPPON K.K. *[35-12]*
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- SEMICONDUCTOR DISPLAY CORP. *[10-22]*
- SENSOFAR TECH SL *[31-12]*
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- SHENZHEN JMT GLASS CO., LTD. *[36-18]*
- NANO TEM CO., LTD. *[13-36]*
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- NIC AUTOTEC, INC. *[22-46]*
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- NIHON SIBERHEGNER K.K. *[26-28]*
- NIKON INSTECH CO., LTD. *[30-003]*
- NIPPON BEARING CO., LTD. *[15-16]*
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- NIPPON PAPER CRECIA CO., LTD. *[22-24]*
- NIPPON ROPER GMBH *[29-3]*
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- NOMURA TRADING CO., LTD. *[37-24]*
- NOVALED AG CORP. *[8-32H]*
- OGINO SEIKI CO., LTD. *[22-4]*
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- PRECISION GRANITE W CO., LTD. *[16-30]*
- PRESS JOURNAL INC. *[40-9]*
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- RIKEN KEIKI CO., LTD. *[33-17]*
- ROKITECHNO CO., LTD. *[33-18]*
- SAEJONG IND *[14-30D]*
- SAKAGUCHI E.H VOC CORP. *[17-9]*
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- SCHNEIDER ASIA PACIFIC LTD. *[8-32A]*
- SE CO., LTD. *[20-001]*
- SEKIGAHARA SEISAKUSHO LTD. *[12-23]*
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- SHELDAHL *[38-24]*
- SHENZHEN KEIRAKU OPTICAL-ELECTRONIC CO., LTD. *[20-30]*

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- SANWA COKEN [22-10]
- SAZUKA INDUSTRIES CO., LTD. [14-3]
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- SE CO., LTD. [20-001]
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- SEMICONDUCTOR DISPLAY CORP. [10-22]
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- SHIN-ETSU CHEMICAL CO., LTD. [36-44]
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- SHINKO ELECTRIC CO., LTD. [31-11]
- SHINKO SEIKI CO., LTD. [18-46]
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- SHODA TECHTRON CORP. [11-10]
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- SOFTAL JAPAN LTD. [18-003]
- SOLUTECH CO., LTD. [25-4]
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- SOMAX CO., LTD. [12-10]
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- THREEBOND CO., LTD. [38-30]
- TNF CORP. [14-30G]
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- TOPRE CORPORATION [41-22]
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- TORAY PRECISION K.K. [19-25]
- TOSHIBA MACHINE CO., LTD. [24-46]
- TOTO LTD. [33-8]
- TOTTORI PREFECTURAL GOVERNMENT [36-003]
- TOUCH PANEL LABORATORIES CO., LTD. [41-44]
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- TOYO INK MFG. CO., LTD. [41-29]
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- TOYO LINT FREE CO., LTD. [21-29]
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- TOYOTA TSUSHO CORP. [38-21]
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- TSUKATANI HAMONO MFG. CO., LTD. [24-10]
- TSUKISHIMA KIKAI CO., LTD. [13-23]
- TTS CORP. [17-24]
- TUNGTAY(KUNSHAN) VACUUM COATING ENGINEERING CO., LTD. [34-36]

- TSUKATANI HAMONO MFG. CO., LTD. *[24-10]*
- TSUKISHIMA KIKAI CO., LTD. *[13-23]*
- TTS CORP. *[17-24]*
- TUNGTAY(KUNSHAN) VACUUM COATING ENGINEERING CO., LTD. *[34-36]*
- UNIBRIGHT CHEMICAL CO., LTD. *[40-32]]*
- URATANI SYOJI CO., LTD. *[26-22]*
- V TECHNOLOGY CO., LTD. *[29-4]*
- VAISALA K.K. *[20-20]*
- VASTVIEW TECHNOLOGY INC. *[34-002]*
- VESSEL CO., INC. *[21-34]*
- WATANABE CO., LTD. *[11-003]*
- WATTY CO., LTD. *[16-10]*
- XEVIOS CORP. *[13-29]*
- YAMABUN ELECTRONICS CO., LTD. *[28-8]*
- YA-MAN LTD. *[28-32]*
- YOKOGAWA BRIDGE CORP. *[14-15]*
- YOKOHAMA OILS&FATS INDUSTRY CO., LTD. *[35-23]*
- YUASA TECHNICAL ENGINEERING CO., LTD. *[12-001]*
- YUMEX INC. *[31-29]*
- ZEON CORP. *[40-24]*

*name of manufacturers are partly provided.

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- THE SEMICONDUCTOR INDUSTRY NEWS
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- ELECTRONIC PARTS AND MATERIALS
- M&E
- MECHATRONICS DESIGN NEWS
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- KBS
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- DISPLAYBANK
- DISPLAY+
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- MOTION CONTROL
- UBI SANUP RESEARCH
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- DIGITIMES
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- ARCO INFOCOMM
- PIDA

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- CHINA ELECTRONICS NEWS
- SHENZHEN YAWEI INFORMATION

■UNITED KINGDOM
- BBC
- MONDIALE PUBLISHING

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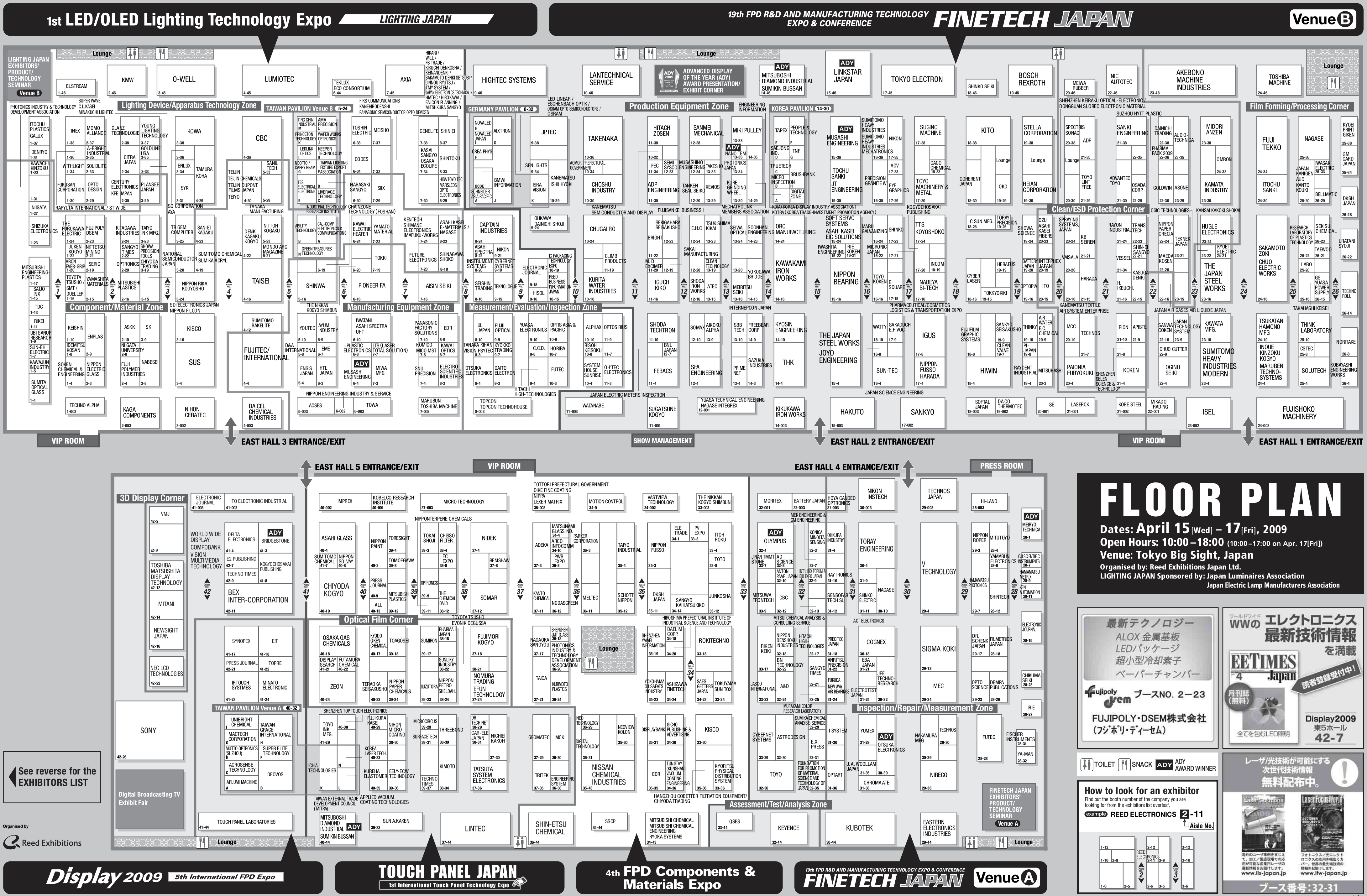
附件2



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附件4

compatibility requirements for a laser energy source that will assure compliance of the laser product with this section and § 1040.11.

(vi) In the case of laser products classified with a 7 millimeter diameter aperture stop as provided in paragraph (e)(3)(i) of this section, if the use of a 50 millimeter diameter aperture stop would result in a higher clsssification of the product, the following warning shall be included in the user information: ''CAUTION—The use of optical instruments with this product will increase eye hazard.''

(2) *Purchasing and servicing information.* Manufacturers of laser products shall provide or cause to be provided:

(i) In all catalogs, specification sheets, and descriptive brochures pertaining to each laser product, a legible reproduction (color optional) of the class designation and warning required by paragraph (g) of this section to be affixed to that product, including the information required for positions 1, 2, and 3 of the applicable logotype (figure 1 of paragraph (g)(1)(ii) or figure 2 of paragraph (g)(2)(ii) of this section).

(ii) To servicing dealers and distributors and to others upon request at a cost not to exceed the cost of preparation and distribution, adequate instructions for service adjustments and service procedures for each laser product model, including clear warnings and precautions to be taken to avoid possible exposure to laser and collateral radiation in excess of the accessible emission limits in tables I, II–A, II, III–A, III–B, and VI of paragraph (d) of this section, and a schedule of maintenance necessary to keep the product in compliance with this section and § 1040.11; and in all such service instructions, a listing of those controls and procedures that could be utilized by persons other than the manufacturers or the manufacturer's agents to increase accessible emission levels of radiation and a clear description of the location of displaceable portions of the protective housing that could allow human access to laser or collateral radiation in excess of the accessible emission limits in tables I, II–A, II, III–A, III–B, and VI of paragraph (d) of this section. The instructions shall include protective procedures for service personnel to avoid exposure to levels of laser and collateral radiation known to be hazardous for each procedure or sequence of procedures to be accomplished, and legible reproductions (color optional) of required labels and hazard warnings.

(i) *Modification of a certified product.* The modification of a laser product, previously certified under § 1010.2, by any person engaged in the business of manufacturing, assembling, or modifying laser products shall be construed as manufacturing under the act if the modification affects any aspect of the product's performance or intended function(s) for which this section and § 1040.11 have an applicable requirement. The manufacturer who performs such modification shall recertify and reidentify the product in accordance with the provisions of §§ 1010.2. and 1010.3.

(The information collection requirements contained in paragraph (a)(3)(ii) were approved by the Office of Management and Budget under control number 0910–0176)

[50 FR 33688, Aug. 20, 1985; 50 FR 42156, Oct. 18, 1985; 65 FR 17138, Mar. 31, 2000]

§ 1040.11 Specific purpose laser products.

(a) *Medical laser products.* Each medical laser product shall comply with all of the applicable requirements of § 1040.10 for laser products of its class. In addition, the manufacturer shall:

(1) Incorporate in each Class III or IV medical laser product a means for the measurement of the level of that laser radiation intended for irradiation of the human body. Such means may have an error in measurement of no more than 20 percent when calibrated in accordance with paragraph (a)(2) of this section. Indication of the measurement shall be in International System Units. The requirements of this paragraph do not apply to any laser radiation that is all of the following:

(i) Of a level less than the accessible limits of Class IIIa; and

(ii) Used for relative positioning of the human body; and

(iii) Not used for irradiation of the human eye for ophthalmic purposes.

(2) Supply with each Class III or IV medical laser product instructions specifying a procedure and schedule for

calibration of the measurement system required by paragraph (a)(1) of this section.

(3) Affix to each medical laser product, in close proximity to each aperture through which is emitted accessible laser radiation in excess of the accessible emission limits of Class I, a label bearing the wording: ''Laser aperture.''

(b) *Surveying, leveling, and alignment laser products.* Each surveying, leveling. or alignment laser product shall comply with all of the applicable requirements of § 1040.10 for a Class I, IIa, II or IIIa laser product and shall not permit human access to laser radiation in excess of the accessible emission limits of Class IIIa.

(c) *Demonstration laser products.* Each demonstration laser product shall comply with all of the applicable requirements of § 1040.10 for a Class I, IIa, II, or IIIa laser product and shall not permit human access to laser radiation in excess of the accessible emission limits of Class I and, if applicable, Class IIa, Class II, or Class IIIa.

[50 FR 33702, Aug. 20, 1985]

§ 1040.20 Sunlamp products and ultraviolet lamps intended for use in sunlamp products.

(a) *Applicability.* (1) The provisions of this section, as amended, are applicable as specified herein to the following products manufactured on or after September 8, 1986.

(i) Any sunlamp product.

(ii) Any ultraviolet lamp intended for use in any sunlamp product.

(2) Sunlamp products and ultraviolet lamps manufactured on or after May 7, 1980, but before September 8, 1986, are subject to the provisions of this section as published in the FEDERAL REGISTER of November 9, 1979 (44 FR 65357).

(b) *Definitions.* As used in this section the following definitions apply:

(1) *Exposure position* means any position, distance, orientation, or location relative to the radiating surfaces of the sunlamp product at which the user is intended to be exposed to ultraviolet radiation from the product, as recommended by the manufacturer.

(2) *Intended* means the same as ''intended uses'' in § 801.4.

(3) *Irradiance* means the radiant power incident on a surface at a specified location and orientation relative to the radiating surface divided by the area of the surface, as the area becomes vanishingly small, expressed in units of watts per square centimeter (W/cm^2).

(4) *Maximum exposure time* means the greatest continuous exposure time interval recommended by the manufacturer of the product.

(5) *Maximum timer interval* means the greatest time interval setting on the timer of a product.

(6) *Protective eyewear* means any device designed to be worn by users of a product to reduce exposure of the eyes to radiation emitted by the product.

(7) *Spectral irradiance* means the irradiance resulting from radiation within a wavelength range divided by the wavelength range as the range becomes vanishingly small, expressed in units of watts per square centimeter per nanometer ($W/(cm^2/nm)$).

(8) *Spectral transmittance* means the spectral irradiance transmitted through protective eyewear divided by the spectral irradiance incident on the protective eyewear.

(9) *Sunlamp product* means any electronic product designed to incorporate one or more ultraviolet lamps and intended for irradiation of any part of the living human body, by ultraviolet radiation with wavelengths in air between 200 and 400 nanometers, to induce skin tanning.

(10) *Timer* means any device incorporated into a product that terminates radiation emission after a preset time interval.

(11) *Ultraviolet lamp* means any lamp that produces ultraviolet radiation in the wavelength interval of 200 to 400 nanometers in air and that is intended for use in any sunlamp product.

(c) *Performance requirements*—(1) *Irradiance ratio limits.* For each sunlamp product and ultraviolet lamp, the ratio of the irradiance within the wavelength range of greater than 200 nanometers through 260 nanometers to the irradiance within the wavelength range of greater than 260 nanometers through 320 nanometers may not exceed 0.003 at any distance and direction from the product or lamp.

Drug Administration, may grant an exemption from one or more of the statements (radiation safety warnings) specified in paragraph (c)(6)(i) of this section. Such exemption shall be based upon a determination by the Director that the microwave oven model for which the exemption is sought should continue to comply with paragraphs (c) (1), (2), and (3) of this section under the adverse condition of use addressed by such precautionary statement(s). An original and two copies of applications shall be submitted to the Dockets Management Branch (HFA–305), Food and Drug Administration, rm. 1–23, 12420 Parklawn Dr., Rockville, MD 20857. Copies of the written portion of the application, including supporting data and information, and the Director's action on the application will be maintained by the Branch for public review. The application shall include:

(*a*) The specific microwave oven model(s) for which the exemption is sought.

(*b*) The specific radiation safety warning(s) from which exemption is sought.

(*c*) Data and information which clearly establish that one or more of the radiation safety warnings in paragraph (c)(6)(i) of this section is not necessary for the specified microwave oven model(s).

(*d*) Such other information and a sample of the applicable product if required by regulation or by the Director, Center for Devices and Radiological Health, to evaluate and act on the application.

[38 FR 28640, Oct. 15, 1973, as amended at 40 FR 14752, Apr. 4, 1975; 40 FR 52007, Nov. 7, 1975; 46 FR 8461, Jan. 27, 1981; 48 FR 57482, Dec. 30, 1983; 50 FR 13566, Apr. 5, 1985; 53 FR 11254, Apr. 6, 1988; 59 FR 14365, Mar. 28, 1994]

PART 1040—PERFORMANCE STANDARDS FOR LIGHT-EMITTING PRODUCTS

Sec.

AUTHORITY: Secs. 501, 502, 510, 515–520, 701, 801 of the Federal Food, Drug, and Cosmetic Act (21 U.S.C. 351, 352, 360, 360e–360j, 371, 381); secs. 354–360F of the Public Health Service Act (42 U.S.C. 263b–263n).

§ 1040.10 Laser products.

(a) *Applicability*. The provisions of this section and § 1040.11, as amended, are applicable as specified to all laser products manufactured or assembled after August 1, 1976, except when:

(1) Such a laser product is either sold to a manufacturer of an electronic product for use as a component (or replacement) in such electronic product, or

(2) Sold by or for a manufacturer of an electronic product for use as a component (or replacement) in such electronic product, provided that such laser product:

(i) Is accompanied by a general warning notice that adequate instructions for the safe installation of the laser product are provided in servicing information available from the complete laser product manufacturer under paragraph (h)(2)(ii) of this section, and should be followed,

(ii) Is labeled with a statement that it is designated for use solely as a component of such electronic product and therefore does not comply with the appropriate requirements of this section and § 1040.11 for complete laser products, and

(iii) Is not a removable laser system as described in paragraph (c)(2) of this section; and

(3) The manufacturer of such a laser product, if manufactured after August 20, 1986:

(i) Registers, and provides a listing by type of such laser products manufactured that includes the product name, model number and laser medium or emitted wavelength(s). The registration and listing shall include the name and address of the manufacturer and shall be submitted to the Director, Office of Compliance (HFZ–300), Center for Devices and Radiological Health, 5600 Fishers Lane, Rockville, MD 20857.

(ii) Maintains and allows access to any sales, shipping, or distribution records that identify the purchaser of such a laser product by name and address, the product by type, the number of units sold, and the date of sale (shipment). These records shall be maintained and made available as specified in § 1002.31.

(b) *Definitions.* As used in this section and § 1040.11, the following definitions apply:

(1) *Accessible emission level* means the magnitude of accessible laser or collateral radiation of a specific wavelength and emission duration at a particular point as measured according to paragraph (e) of this section. Accessible laser or collateral radiation is radiation to which human access is possible, as defined in paragraphs (b) (12), (15), and (22) of this section.

(2) *Accessible emission limit* means the maximum accessible emission level permitted within a particular class as set forth in paragraphs (c), (d), and (e) of this section.

(3) *Aperture* means any opening in the protective housing or other enclosure of a laser product through which laser or collateral radiation is emitted, thereby allowing human access to such radiation.

(4) *Aperture stop* means an opening serving to limit the size and to define the shape of the area over which radiation is measured.

(5) *Class I laser product* means any laser product that does not permit access during the operation to levels of laser radiation in excess of the accessible emission limits contained in Table I of paragraph (d) of this section.[1]

(6) *Class IIa laser product* means any laser product that permits human access during operation to levels of visible laser radiation in excess of the accessible emission limits contained in Table I, but does not permit human access during operation to levels of laser radiation in excess of the accessible emission limits contained in Table II–A of paragraph (d) of this section.[2]

(7) *Class II laser product* means any laser product that permits human access during operation to levels of visible laser radiation in excess of the accessible emission limits contained in Table II–A, but does not permit human access during operation to levels of laser radiation in excess of the accessible emission limits contained in Table II of paragraph (d) of this section.[3]

(8) *Class IIIa laser product* means any laser product that permits human access during operation to levels of visible laser radiation in excess of the accessible emission limits contained in Table II, but does not permit human access during operation to levels of laser radiation in excess of the accessible emission limits contained in Table III–A of paragraph (d) of this section.[4]

(9) *Class IIIb laser product* means any laser product that permits human access during operation to levels of laser radiation in excess of the accessible emission limits of Table III–A, but does not permit human access during operation to levels of laser radiation in excess of the accessible emission limits contained in Table III–B of paragraph (d) of this section.[5]

(10) *Class III laser product* means any Class IIIa or Class IIIb laser product.

(11) *Class IV laser product* means any laser that permits human access during operation to levels of laser radiation in excess of the accessible emission limits contained in Table III–B of paragraph (d) of this section.[6]

(12) *Collateral radiation* means any electronic product radiation, except laser radiation, emitted by a laser product as a result of the operation of the laser(s) or any component of the laser product that is physically necessary for the operation of the laser(s).

[1] Class I levels of laser radiation are not considered to be hazardous.

[2] Class IIa levels of laser radiation are not considered to be hazardous if viewed for any period of time less than or equal to 1×10^3 seconds but are considered to be a chronic viewing hazard for any period of time greater than 1×10^3 seconds.

[3] Class II levels of laser radiation are considered to be a chronic viewing hazard.

[4] Class IIIa levels of laser radiation are considered to be, depending upon the irradiance, either an acute intrabeam viewing hazard or chronic viewing hazard, and an acute viewing hazard if viewed directly with optical instruments.

[5] Class IIIb levels of laser radiation are considered to be an acute hazard to the skin and eyes from direct radiation.

[6] Class IV levels of laser radiation are considered to be an acute hazard to the skin and eyes from direct and scattered radiation.

(13) *Demonstration laser product* means any laser product manufactured, designed, intended, or promoted for purposes of demonstration, entertainment, advertising display, or artistic composition. The term ''demonstration laser product'' does not apply to laser products which are not manufactured, designed, intended, or promoted for such purposes, even though they may be used for those purposes or are intended to demonstrate other applications.

(14) *Emission duration* means the temporal duration of a pulse, a series of pulses, or continuous operation, expressed in seconds, during which human access to laser or collateral radiation could be permitted as a result of operation, maintenance, or service of a laser product.

(15) *Human access* means the capacity to intercept laser or collateral radiation by any part of the human body. For laser products that contain Class IIIb or IV levels of laser radiation, ''human access'' also means access to laser radiation that can be reflected directly by any single introduced flat surface from the interior of the product through any opening in the protective housing of the product.

(16) *Integrated radiance* means radiant energy per unit area of a radiating surface per unit solid angle of emission, expressed in joules per square centimeter per steradian ($J cm^{-2} sr^{-1}$).

(17) *Invisible radiation* means laser or collateral radiation having wavelengths of equal to or greater than 180 nm but less than or equal to 400 nm or greater than 710 nm but less than or equal to 1.0×10^6 nm (1 millimeter).

(18) *Irradiance* means the time-averaged radiant power incident on an element of a surface divided by the area of that element, expressed in watts per square centimeter ($W cm^{-2}$).

(19) *Laser* means any device that can be made to produce or amplify electromagnetic radiation at wavelenghts greater than 250 nm but less than or equal to 13,000 nm or, after August 20, 1986, at wavelengths equal to or greater than 180 nm but less than or equal to 1.0×10^6 nm primarily by the process of controlled stimulated emission.

(20) *Laser energy source* means any device intended for use in conjunction with a laser to supply energy for the operation of the laser. General energy sources such as electrical supply mains or batteries shall not be considered to constitute laser energy sources.

(21) *Laser product* means any manufactured product or assemblage of components which constitutes, incorporates, or is intended to incorporate a laser or laser system. A laser or laser system that is intended for use as a component of an electronic product shall itself be considered a laser product.

(22) *Laser radiation* means all electromagnetic radiation emitted by a laser product within the spectral range specified in paragraph (b)(19) of this section that is produced as a result of controlled stimulated emission or that is detectable with radiation so produced through the appropriate aperture stop and within the appropriate solid angle of acceptance, as specified in paragraph (e) of this section.

(23) *Laser system* means a laser in combination with an appropriate laser energy source with or without additional incorporated components. See paragraph (c)(2) of this section for an explanation of the term ''removable laser system.''

(24) *Maintenance* means performance of those adjustments or procedures specified in user information provided by the manufacturer with the laser product which are to be performed by the user for the purpose of assuring the intended performance of the product. It does not include operation or service as defined in paragraph (b) (27) and (38) of this section.

(25) *Maximum output* means the maximum radiant power and, where applicable, the maximum radiant energy per pulse of accessible laser radiation emitted by a laser product during operation, as determined under paragraph (e) of this section.

(26) *Medical laser product* means any laser product which is a medical device as defined in 21 U.S.C. 321(h) and is manufactured, designed, intended or promoted for in vivo laser irradiation of any part of the human body for the purpose of: (i) Diagnosis, surgery, or therapy; or (ii) relative positioning of the human body.

(27) *Operation* means the performance of the laser product over the full range of its functions. It does not include maintenance or service as defined in paragraphs (b) (24) and (38) of this section.

(28) *Protective housing* means those portions of a laser product which are designed to prevent human access to laser or collateral radiation in excess of the prescribed accessible emission limits under conditions specified in this section and in § 1040.11.

(29) *Pulse duration* means the time increment measured between the half-peak-power points at the leading and trailing edges of a pulse.

(30) *Radiance* means time-averaged radiant power per unit area of a radiating surface per unit solid angle of emission, expressed in watts per square centimeter per steradian ($W\ cm^{-2}\ sr^{-1}$).

(31) *Radiant energy* means energy emitted, transferred or received in the form of radiation, expressed in joules (J).

(32) *Radiant exposure* means the radiant energy incident on an element of a surface divided by the area of the element, expressed in joules per square centimeter (Jcm^{-2})

(33) *Radiant power* means time-averaged power emitted, transferred or received in the form of radiation, expressed in watts (W).

(34) *Remote interlock connector* means an electrical connector which permits the connection of external remote interlocks.

(35) *Safety interlock* means a device associated with the protective housing of a laser product to prevent human access to excessive radiation in accordance with paragraph (f)(2) of this section.

(36) *Sampling interval* means the time interval during which the level of accessible laser or collateral radiation is sampled by a measurement process. The magnitude of the sampling interval in units of seconds is represented by the symbol (*t*).

(37) *Scanned laser radiation* means laser radiation having a time-varying direction, origin or pattern of propagation with respect to a stationary frame of reference.

(38) *Service* means the performance of those procedures or adjustments described in the manufacturer's service instructions which may affect any aspect of the product's performance for which this section and § 1040.11 have applicable requirements. It does not include maintenance or operation as defined in paragraphs (b) (24) and (27) of this section.

(39) *Surveying, leveling, or alignment laser product* means a laser product manufactured, designed, intended or promoted for one or more of the following uses:

(i) Determining and delineating the form, extent, or position of a point, body, or area by taking angular measurement.

(ii) Positioning or adjusting parts in proper relation to one another.

(iii) Defining a plane, level, elevation, or straight line.

(40) *Visible radiation* means laser or collateral radiation having wavelengths of greater than 400 nm but less than or equal to 710 nm.

(41) *Warning logotype* means a logotype as illustrated in either Figure 1 or Figure 2 of paragraph (g) of this section.

(42) *Wavelength* means the propagation wavelength in air of electromagnetic radiation.

(c) *Classification of laser products*— (1) *All laser products.* Each laser product shall be classified in Class I, IIa, II, IIIa, IIIb, or IV in accordance with definitions set forth in paragraphs (b) (5) through (11) of this section. The product classification shall be based on the highest accessible emission level(s) of laser radiation to which human access is possible during operation in accordance with paragraphs (d), (e), and (f)(1) of this section.

(2) *Removable laser systems.* Any laser system that is incorporated into a laser product subject to the requirements of this section and that is capable, without modification, of producing laser radiation when removed from such laser product, shall itself be considered a laser product and shall be separately subject to the applicable requirements in this subchapter for laser products of its class. It shall be classified on the basis of accessible emission of laser radiation when so removed.

(d) *Accessible emission limits.* Accessible emission limits for laser radiation in each class are specified in Tables I, II–A, II, III–A, and III–B of this paragraph. The factors, k_1 and k_2 vary with wavelength and emission duration. These factors are given in Table IV of this paragraph, with selected numerical values in Table V of this paragraph. Accessible emission limits for collateral radiation are specified in Table VI of this paragraph.

NOTES APPLICABLE TO TABLES I, II–A, II, III–A AND III–B:

(1) The factors k_1 and k_2 are wavelength-dependent correction factors determined from Table IV.

(2) The variable t in the expressions of emission limits is the magnitude of the sampling interval in units of seconds.

TABLE I

CLASS I ACCESSIBLE EMISSION LIMITS FOR LASER RADIATION

Wavelength (nanometers)	Emission duration (seconds)	Class I-Accessible emission limits (value)	(unit)	(quantity)**
≥ 180 but ≤ 400	$\leq 3.0 \times 10^{4}$	$2.4 \times 10^{-5} k_1 k_2$*	Joules(J)*	radiant energy
	$>3.0 \times 10^{4}$	$8.0 \times 10^{-10} k_1 k_2$*	Watts(W)*	radiant power
>400 but ≤ 1400	$>1.0 \times 10^{-9}$ to 2.0×10^{-5}	$2.0 \times 10^{-7} k_1 k_2$	J	radiant energy
	$>2.0 \times 10^{-5}$ to 1.0×10^{1}	$7.0 \times 10^{-4} k_1 k_2 t^{3/4}$	J	radiant energy
	$>1.0 \times 10^{1}$ to 1.0×10^{4}	$3.9 \times 10^{-3} k_1 k_2$	J	radiant energy
	$>1.0 \times 10^{4}$	$3.9 \times 10^{-7} k_1 k_2$	W	radiant power
	and also (See paragraph (d)(4) of this section)			
	$>1.0 \times 10^{-9}$ to 1.0×10^{1}	$10 k_1 k_2 t^{1/3}$	$Jcm^{-2}sr^{-1}$	integrated radiance
	$>1.0 \times 10^{1}$ to 1.0×10^{4}	$20 k_1 k_2$	$Jcm^{-2}sr^{-1}$	integrated radiance
	$>1.0 \times 10^{4}$	$2.0 \times 10^{-3} k_1 k_2$	$Wcm^{-2}sr^{-1}$	radiance
>1400 but ≤ 2500	$>1.0 \times 10^{-9}$ to 1.0×10^{-7}	$7.9 \times 10^{-5} k_1 k_2$	J	radiant energy
	$>1.0 \times 10^{-7}$ to 1.0×10^{1}	$4.4 \times 10^{-3} k_1 k_2 t^{1/4}$	J	radiant energy
	$>1.0 \times 10^{1}$	$7.9 \times 10^{-4} k_1 k_2$	W	radiant power
>2500 but $\leq 1.0 \times 10^{6}$	$>1.0 \times 10^{-9}$ to 1.0×10^{-7}	$1.0 \times 10^{-2} k_1 k_2$	Jcm^{-2}	radiant exposure
	$>1.0 \times 10^{-7}$ to 1.0×10^{1}	$5.6 \times 10^{-1} k_1 k_2 t^{1/4}$	Jcm^{-2}	radiant exposure
	$>1.0 \times 10^{1}$	$1.0 \times 10^{-1} k_1 k_2 t$	Jcm^{-2}	radiant exposure

*Class I accessible emission limits for wavelengths equal to or greater than 180 nm but less than or equal to 400 nm shall not exceed the Class I accessible emission limits for the wavelengths greater than 1400 nm but less than or equal to 1.0×10^{6} nm with a k_1 and k_2 of 1.0 for comparable sampling intervals.

**Measurement parameters and test conditions shall be in accordance with paragraphs (d)(1), (2), (3), and (4), and (e) of this section.

TABLE II–A

CLASS IIa ACCESSIBLE EMISSION LIMITS FOR LASER RADIATION

CLASS IIa ACCESSIBLE EMISSION LIMITS ARE IDENTICAL TO CLASS I ACCESSIBLE EMISSION LIMITS EXCEPT WITHIN THE FOLLOWING RANGE OF WAVELENGTHS AND EMISSION DURATIONS:

Wavelength	Emission duration	Class IIa-Accessible emission limits		
(nanometers)	(seconds)	(value)	(unit)	(quantity)*
>400 but ≤710	>1.0 X 10^3	3.9 X 10^{-6}	W	radiant power

*Measurement parameters and test conditions shall be in accordance with paragraphs (d)(1), (2), (3), and (4), and (e) of this section.

TABLE II

CLASS II ACCESSIBLE EMISSION LIMITS FOR LASER RADIATION

CLASS II ACCESSIBLE EMISSION LIMITS ARE IDENTICAL TO CLASS I ACCESSIBLE EMISSION LIMITS EXCEPT WITHIN THE FOLLOWING RANGE OF WAVELENGTHS AND EMISSION DURATIONS:

Wavelength	Emission duration	Class II-Accessible emission limits		
(nanometers)	(seconds)	(value)	(unit)	(quantity)*
>400 but ≤710	>2.5 X 10^{-1}	1.0 X 10^{-3}	W	radiant power

*Measurement parameters and test conditions shall be in accordance with paragraphs (d)(1), (2), (3), and (4), and (e) of this section.

TABLE III-A

CLASS IIIa ACCESSIBLE EMISSION LIMITS FOR LASER RADIATION

CLASS IIIa ACCESSIBLE EMISSION LIMITS ARE IDENTICAL TO CLASS I ACCESSIBLE EMISSION LIMITS EXCEPT WITHIN THE FOLLOWING RANGE OF WAVELENGTHS AND EMISSION DURATIONS:

Wavelength	Emission duration	Class IIIa-Accessible emission limits		
(nanometers)	(seconds)	(value)	(unit)	(quantity)*
>400 but ≤710	$>3.8 \times 10^{-4}$	5.0×10^{-3}	W	radiant power

*Measurement parameters and test conditions shall be in accordance with paragraphs (d)(1), (2), (3), and (4), and (e) of this section.

TABLE III-B

CLASS IIIb ACCESSIBLE EMISSION LIMITS FOR LASER RADIATION

Wavelength	Emission duration	Class IIIb-Accessible emission limits		
(nanometers)	(seconds)	(value)	(unit)	(quantity)*
≥180 but ≤400	$\leq 2.5 \times 10^{-1}$	$3.8 \times 10^{-4} k_1 k_2$	J	radiant energy
	$>2.5 \times 10^{-1}$	$1.5 \times 10^{-3} k_1 k_2$	W	radiant power
>400 but ≤1400	$>1.0 \times 10^{-9}$ to 2.5×10^{-1}	$10 k_1 k_2 t^{1/3}$ to a maximum value of 10	Jcm^{-2}	radiant exposure
			Jcm^{-2}	radiant exposure
	$>2.5 \times 10^{-1}$	5.0×10^{-1}	W	radiant power
>1400 but ≤1.0 X 10^6	$>1.0 \times 10^{-9}$ to 1.0×10^{1}	10	Jcm^{-2}	radiant exposure
	$>1.0 \times 10^{1}$	5.0×10^{-1}	W	radiant power

*Measurement parameter and test conditions shall be in accordance with paragraphs (d)(1), (2), (3), and (4), and (e) of this section.

TABLE IV

VALUES OF WAVELENGTH DEPENDENT CORRECTION FACTORS k_1 AND k_2

Wavelength (nanometers)	k_1	k_2		
180 to 302.4	1.0	1.0		
> 302.4 to 315	$10^{\left[\frac{\lambda - 302.4}{5}\right]}$	1.0		
> 315 to 400	330.0	1.0		
> 400 to 700	1.0	1.0		
> 700 to 800	$10^{\left[\frac{\lambda - 700}{515}\right]}$	if: $t \le \frac{10100}{\lambda - 699}$ then: $k_2 = 1.0$	if: $\frac{10100}{\lambda - 699} < t \le 10^4$ then: $k_2 = \frac{t(\lambda - 699)}{10100}$	if: $t > 10^4$ then: $k_2 = \frac{\lambda - 699}{1.01}$
> 800 to 1060	$10^{\left[\frac{\lambda - 700}{515}\right]}$	if: $t \le 100$ then: $k_2 = 1.0$	if: $100 < t \le 10^4$ then: $k_2 = \frac{t}{100}$	if: $t > 10^4$ then: $k_2 = 100$
> 1060 to 1400	5.0			
> 1400 to 1535	1.0	1.0		
> 1535 to 1545	$t \le 10^{-7}$ $k_1 = 100.0$ $t > 10^{-7}$ $k_1 = 1.0$	1.0		
> 1545 to 1.0×10^6	1.0	1.0		

Note: The variables in the expressions are the magnitudes of the sampling interval(t), in units of seconds, and the wavelength (λ), in units of nanometers.

TABLE V

SELECTED NUMERICAL SOLUTIONS FOR k_1 AND k_2

Wavelength (nanometers)	k_1	k_2				
		$t \leq 100$	t=300	t=1000	t=3000	$t \geq 10{,}000$
180	1.0	1.0				
300	1.0					
302	1.0					
303	1.32					
304	2.09					
305	3.31					
306	5.25					
307	8.32					
308	13.2					
309	20.9					
310	33.1					
311	52.5					
312	83.2					
313	132.0					
314	209.0					
315	330.0					
400	330.0					
401	1.0					
500	1.0					
600	1.0					
700	1.0					
710	1.05	1	1	1.1	3.3	11.0
720	1.09	1	1	2.1	6.3	21.0
730	1.14	1	1	3.1	9.3	31.0
740	1.20	1	1.2	4.1	12.0	41.0
750	1.25	1	1.5	5.0	15.0	50.0
760	1.31	1	1.8	6.0	18.0	60.0
770	1.37	1	2.1	7.0	21.0	70.0
780	1.43	1	2.4	8.0	24.0	80.0
790	1.50	1	2.7	9.0	27.0	90.0
800	1.56	1	3.0	10.0	30.0	100.0
850	1.95	1	3.0	10.0	30.0	100.0
900	2.44	1	3.0	10.0	30.0	100.0
950	3.05	1	3.0	10.0	30.0	100.0
1000	3.82	1	3.0	10.0	30.0	100.0
1050	4.78	1	3.0	10.0	30.0	100.0
1060	5.00	1	3.0	10.0	30.0	100.0
1100	5.00	1	3.0	10.0	30.0	100.0
1400	5.00	1	3.0	10.0	30.0	100.0
1500	1.0	1.0				
1540	100.0*					
1600	1.0					
1.0×10^6	1.0					

* The factor k_1 = 100.0 when $t \leq 10^{-7}$, and k_1 = 1.0 when $t > 10^{-7}$

Note: The variable (t) is the magnitude of the sampling interval in units of seconds.

TABLE VI

ACCESSIBLE EMISSION LIMITS FOR COLLATERAL RADIATION FROM LASER PRODUCTS

1. Accessible emission limits for collateral radiation having wavelengths greater than 180 nanometers but less than or equal to 1.0×10^{6} nanometers are identical to the accessible emission limits of Class I laser radiation, as determined from Tables I and IV in this paragraph.

i. In the wavelength range of less than or equal to 400 nanometers, for all emission durations;

ii. In the wavelength range of greater than 400 nanometers, for all emission durations less than or equal to 1×10^{3} seconds and, when applicable under paragraph (f)(8) of this section, for all emission durations.

2. Accessible emission limit for collateral radiation within the x-ray range of wavelengths is 0.5 milliroentgen in an hour, averaged over a cross-section parallel to the external surface of the product, having an area of 10 square centimeters with no dimension greater than 5 centimeters.

(1) *Beam of a single wavelength.* Laser or collateral radiation of a single wavelength exceeds the accessible emission limits of a class if its accessible emission level is greater than the accessible emission limit of that class within any of the ranges of emission duration specified in Tables I, II–A, II, III–A, and III–B of this paragraph.

(2) *Beam of multiple wavelengths in same range.* Laser or collateral radiation having two or more wavelengths within any one of the wavelength ranges specified in Tables I, II–A, II, III–A, and III–B of this paragraph exceeds the accessible emission limits of a class if the sum of the ratios of the accessible emission level to the corresponding accessible emission limit at each such wavelength is greater than unity for that combination of emission duration and wavelength distribution which results in the maximum sum.

(3) *Beam with multiple wavelengths in different ranges.* Laser or collateral radiation having wavelengths within two or more of the wavelength ranges specified in Tables I, II–A, II, III–A, and III–B of this paragraph exceeds the accessible emission limits of a class if it exceeds the applicable limits within any one of those wavelength ranges. This determination is made for each wavelength range in accordance with paragraph (d) (1) or (2) of this section.

(4) *Class I dual limits.* Laser or collateral radiation in the wavelength range of greater than 400 nm but less than or equal to 1.400 nm exceeds the accessible emission limits of Class I if it exceeds both:

(i) The Class I accessible emission limits for radiant energy within any range of emission duration specified in Table I of this paragraph, and

(ii) The Class I accessible emission limits for integrated radiance within any range of emission duration specified in Table I of this paragraph.

(e) *Tests for determination of compliance*—(1) *Tests for certification.* Tests on which certification under § 1010.2 is based shall account for all errors and statistical uncertainties in the measurement process. Because compliance with the standard is required for the useful life of a product such tests shall also account for increases in emission and degradation in radiation safety with age.

(2) *Test conditions.* Except as provided in § 1010.13, tests for compliance with each of the applicable requirements of this section and § 1040.11 shall be made during operation, maintenance, or service as appropriate:

(i) Under those conditions and procedures which maximize the accessible emission levels, including start-up, stabilized emission, and shut-down of the laser product; and

(ii) With all controls and adjustments listed in the operation, maintenance, and service instructions adjusted in combination to result in the maximum accessible emission level of radiation; and

(iii) At points in space to which human access is possible in the product configuration which is necessary to determine compliance with each requirement, e.g., if operation may require removal of portions of the protective housing and defeat of safety interlocks, measurements shall be made at points accessible in that product configuration; and

(iv) With the measuring instrument detector so positioned and so oriented with respect to the laser product as to result in the maximum detection of radiation by the instrument; and

(v) For a laser product other than a laser system, with the laser coupled to that type of laser energy source which is specified as compatible by the laser product manufacturer and which produces the maximum emission level of accessible radiation from that product.

(3) *Measurement parameters.* Accessible emission levels of laser and collateral radiation shall be based upon the following measurements as appropriate, or their equivalent:

(i) For laser products intended to be used in a locale where the emitted laser radiation is unlikely to be viewed with optical instruments, the radiant power (W) or radiant energy (J) detectable through a circular aperture stop having a diameter of 7 millimeters and within a circular solid angle of acceptance of 1 X 10^{-3} steradian with collimating optics of 5 diopters or less. For scanned laser radiation, the direction of the solid angle of acceptance shall change as needed to maximize detectable radiation, with an angular speed of up to 5 radians/second. A 50 millimeter diameter aperture stop with the same collimating optics and acceptance angle stated above shall be used for all other laser products (except that a 7 millimeter diameter aperture stop shall be used in the measurement of scanned laser radiation emitted by laser products manufactured on or before August 20, 1986.

(ii) The irradiance (W cm^{-2}) or radiant exposure (J cm^{-2} equivalent to the radiant power (W) or radiant energy (J) detectable through a circular aperture stop having a diameter of 7 millimeters and, for irradiance, within a circular solid angle of acceptance of 1 x 10^{-3} steradian with collimating optics of 5 diopters or less, divided by the area of the aperture stop (cm^{-2}).

(iii) The radiance (W cm^{-2} sr^{-1}) or integrated radiance (J cm^{-2} sr^{-1}) equivalent to the radiant power (W) or radiant energy (J) detectable through a circular aperture stop having a diameter of 7 millimeters and within a circular solid angle of acceptance of 1 X 10^{-5} steradian with collimating optics of 5 diopters or less, divided by that solid angle (sr) and by the area of the aperture stop (cm^{-2}).

(f) *Performance requirements*—(1) *Protective housing.* Each laser product shall have a protective housing that prevents human access during operation to laser and collateral radiation that exceed the limits of Class I and Table VI, respectively, wherever and whenever such human access is not necessary for the product to perform its intended function. Wherever and whenever human access to laser radiation levels that exceed the limits of Class I is necessary, these levels shall not exceed the limits of the lowest class necessary to perform the intended function(s) of the product.

(2) *Safety interlocks.* (i) Each laser product, regardless of its class, shall be provided with at least one safety interlock for each portion of the protective housing which is designed to be removed or displaced during operation or maintenance, if removal or displacement of the protective housing could permit, in the absence of such interlock(s), human access to laser or collateral radiation in excess of the accessible emission limit applicable under paragraph (f)(1) of this section.

(ii) Each required safety interlock, unless defeated, shall prevent such human access to laser and collateral radiation upon removal or displacement of such portion of the protective housing

(iii) Either multiple safety interlocks or a means to preclude removal or displacement of the interlocked portion of the protective housing shall be provided, if failure of a single interlock would allow;

(*a*) Human access to a level of laser radiation in excess of the accessible emission limits of Class IIIa; or

(*b*) Laser radiation in excess of the accessible emission limits of Class II to be emitted directly through the opening created by removal or displacement of the interlocked portion of the protective housing.

(iv) Laser products that incorporate safety interlocks designed to allow safety interlock defeat shall incorporate a means of visual or aural indication of interlock defeat. During interlock defeat, such indication shall be visible or audible whenever the laser product is energized, with and without the associated portion of the protective housing removed or displaced.

(v) Replacement of a removed or displaced portion of the protective housing shall not be possible while required safety interlocks are defeated.

(3) *Remote interlock connector.* Each laser system classified as a Class IIIb or IV laser product shall incorporate a readily available remote interlock connector having an electrical potential difference of no greater than 130 root-mean-square volts between terminals. When the terminals of the connector are not electrically joined, human access to all laser and collateral radiation from the laser product in excess of the accessible emission limits of Class I and Table VI shall be prevented.

(4) *Key control.* Each laser system classified as a Class IIIb or IV laser product shall incorporate a key-actuated master control. The key shall be removable and the laser shall not be operable when the key is removed.

(5) *Laser radiation emission indicator.* (i) Each laser system classified as a Class II or IIIa laser product shall incorporate an emission indicator that provides a visible or audible signal during emission of accessible laser radiation in excess of the accessible emission limits of Class I.

(ii) Each laser system classified as a Class IIIb or IV laser product shall incorporate an emission indicator which provides a visible or audible signal during emission of accessible laser radiation in excess of the accessible emission limits of Class I, and sufficiently prior to emission of such radiation to allow appropriate action to avoid exposure to the laser radiation.

(iii) For laser systems manufactured on or before August 20, 1986, if the laser and laser energy source are housed separately and can be operated at a separation distance of greater than 2 meters, both laser and laser energy source shall incorporate an emission indicator as required in accordance with paragraph (f)(5) (i) or (ii) of this section. For laser systems manufactured after August 20, 1986, each separately housed laser and operation control of a laser system that regulates the laser or collateral radiation emitted by a product during operation shall incorporate an emission indicator as required in accordance with paragraph (f)(5) (i) or (ii) of this section, if the laser or operation control can be operated at a separation distance greater than 2 meters from any other separately housed portion of the laser product incorporating an emission indicator.

(iv) Any visible signal required by paragraph (f)(5) (i) or (ii) of this section shall be clearly visible through protective eyewear designed specifically for the wavelength(s) of the emitted laser radiation.

(v) Emission indicators required by paragraph (f)(5) (i) or (ii) of this section shall be located so that viewing does not require human exposure to laser or collateral radiation in excess of the accessible emission limits of Class I and Table VI.

(6) *Beam attenuator.* (i) Each laser system classified as a Class II, III, or IV laser product shall be provided with one or more permanently attached means, other than laser energy source switch(es), electrical supply main connectors, or the key-actuated master control, capable of preventing access by any part of the human body to all laser and collateral radiation in excess of the accessible emission limits of Class I and Table VI.

(ii) If the configuration, design, or function of the laser product would make unnecessary compliance with the requirement in paragraph (f)(6)(i) of this section, the Director, Office of Compliance (HFZ–300), Center for Devices and Radiological Health, may, upon written application by the manufacturer, approve alternate means to accomplish the radiation protection provided by the beam attenuator.

(7) *Location of controls.* Each Class IIa, II, III, or IV laser product shall have operational and adjustment controls located so that human exposure to laser or collateral radiation in excess of the accessible emission limits of Class I and Table VI is unnecessary for operation or adjustment of such controls.

(8) *Viewing optics.* All viewing optics, viewports, and display screens incorporated into a laser product, regardless of its class, shall limit the levels of laser and collateral radiation accessible to the human eye by means of such viewing optics, viewports, or display screens during operation or maintenance to less than the accessible emission limits of Class I and Table VI. For any shutter or variable attenuator incorporated into such viewing optics, viewports, or display screens, a means shall be provided:

(i) To prevent access by the human eye to laser and collateral radiation in excess of the accessible emission limits of Class I and Table VI whenever the shutter is opened or the attenuator varied.

(ii) To preclude, upon failure of such means as required in paragraph (f)(8)(i) of this section, opening the shutter or varying the attenuator when access by the human eye is possible to laser or collateral radiation in excess of the accessible emission limits of Class I and Table VI.

(9) *Scanning safeguard.* Laser products that emit accessible scanned laser radiation shall not, as a result of any failure causing a change in either scan velocity or amplitude, permit human access to laser radiation in excess of:

(i) The accessible emission limits of the class of the product, or

(ii) The accessible emission limits of the class of the scanned laser radiation if the product is Class IIIb or IV and the accessible emission limits of Class IIIa would be exceeded solely as result of such failure.

(10) *Manual reset mechanism.* Each laser system manufactured after August 20, 1986, and classified as a Class IV laser product shall be provided with a manual reset to enable resumption of laser radiation emission after interruption of emission caused by the use of a remote interlock or after an interruption of emission in excess of 5 seconds duration due to the unexpected loss of main electrical power.

(g) *Labeling requirements.* In addition to the requirements of §§ 1010.2 and 1010.3, each laser product shall be subject to the applicable labeling requirements of this paragraph.

(1) *Class IIa and II designations and warnings.* (i) Each Class IIa laser product shall have affixed a label bearing the following wording: ''Class IIa Laser Product—Avoid Long-Term Viewing of Direct Laser Radiation.''

(ii) Each Class II laser product shall have affixed a label bearing the warning logotype A (Figure 1 in this paragraph) and including the following wording:

[Position I on the logotype]

"LASER RADIATION—DO NOT STARE INTO BEAM"; and

[Position 3 on the logotype]

"CLASS II LASER PRODUCT".

WARNING LOGOTYPE A

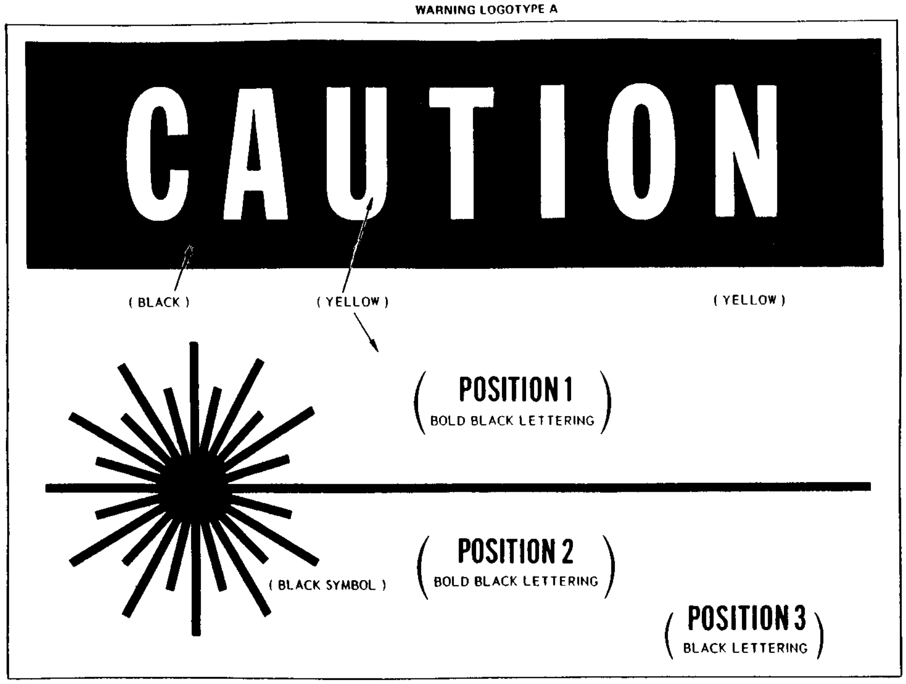


FIGURE 1

(2) *Class IIIa and IIIb designations and warnings.* (i) Each Class IIIa laser product with an irradiance less than or equal to 2.5×10^{-3} W cm^{2-} shall have affixed a label bearing the warning logotype A (Figure 1 of paragraph (g)(1)(ii) of this section) and including the following wording:

[Position 1 on the logotype]

"LASER RADIATION—DO NOT STARE INTO BEAM OR VIEW DIRECTLY WITH OPTICAL INSTRUMENTS"; and,

[Position 3 on the logotype]

"CLASS IIIa LASER PRODUCT".

(ii) Each Class IIIa laser product with an irradiance greater than 2.5×10^{-3} W cm^{-2} shall have affixed a label bearing the warning logotype B (Figure 2 in this paragraph) and including the following wording:

[Position 1 on the logotype]

"LASER RADIATION—AVOID DIRECT EYE EXPOSURE"; and,

[Position 3 on the logotype]

"CLASS IIIa LASER PRODUCT".

WARNING LOGOTYPE B

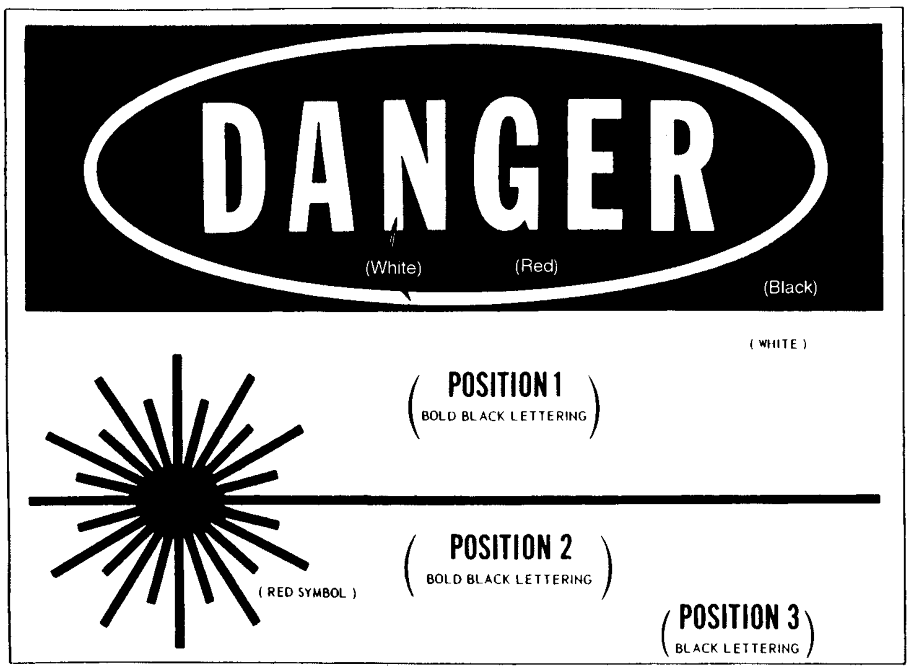


FIGURE 2

(iii) Each Class IIIb laser product shall have affixed a label bearing the warning logotype B (Figure 2 of paragraph (g)(2)(ii) of this section) and including the following wording:

[Position 1 on the logotype]

"LASER RADIATION—AVOID DIRECT EXPOSURE TO BEAM"; and,

[Position 3 on the logotype]

"CLASS IIIb LASER PRODUCT".

(3) *Class IV designation and warning.* Each Class IV laser product shall have affixed a label bearing the warning logotype B (Figure 2 of paragraph (g)(2)(ii) of this section), and including the following wording:

[Position 1 on the logotype]

"LASER RADIATION—AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION"; and,

[Position 3 on the logotype]

"CLASS IV LASER PRODUCT".

(4) *Radiation output information on warning logotype.* Each Class II, III, and IV laser product shall state in appropriate units, at position 2 on the required warning logotype, the maximum

output of laser radiation, the pulse duration when appropriate, and the laser medium or emitted wavelength(s).

(5) *Aperture label.* Each laser product, except medical laser products and Class IIa laser products, shall have affixed, in close proximity to each aperture through which is emitted accessible laser or collateral radiation in excess of the accessible emission limits of Class I and Table VI of paragraph (d) of this section, a label(s) bearing the following wording as applicable.

(i) ''AVOID EXPOSURE—Laser radiation is emitted from this aperture,'' if the radiation emitted through such aperture is laser radiation.

(ii) ''AVOID EXPOSURE—Hazardous electromagnetic radiation is emitted from this aperture,'' if the radiation emitted through such aperture is collateral radiation described in Table VI, item 1.

(iii) ''AVOID EXPOSURE—Hazardous x-rays are emitted from this aperture,'' if the radiation emitted through such aperture is collateral radiation described in Table VI, item 2.

(6) *Labels for noninterlocked protective housings.* For each laser product, labels shall be provided for each portion of the protective housing which has no safety interlock and which is designed to be displaced or removed during operation, maintenance, or service, and thereby could permit human access to laser or collateral radiation in excess of the limits of Class I and Table VI. Such labels shall be visible on the protective housing prior to displacement or removal of such portion of the protective housing and visible on the product in close proximity to the opening created by removal or displacement of such portion of the protective housing, and shall include the wording:

(i) ''CAUTION—Laser radiation when open. DO NOT STARE INTO BEAM.'' for Class II accessible laser radiation.

(ii) ''CAUTION—Laser radiation when open. DO NOT STARE INTO BEAM OR VIEW DIRECTLY WITH OPTICAL INSTRUMENTS.'' for Class IIIa accessible laser radiation with an irradiance less than or equal to 2.5×10^{-3} W cm^{-2}.

(iii) ''DANGER—Laser radiation when open. AVOID DIRECT EYE EXPOSURE.'' for Class IIIa accessible laser radiation with an irradiance greater than 2.5×10^{-3} W cm^{-2}.

(iv) ''DANGER—Laser radiation when open. AVOID DIRECT EXPOSURE TO BEAM.'' for Class IIIb accessible laser radiation.

(v) ''DANGER—Laser radiation when open. AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION.'' for Class IV accessible laser radiation.

(vi) ''CAUTION—Hazardous electromagnetic radiation when open.'' for collateral radiation in excess of the accessible emission limits in Table VI, item 1 of paragraph (d) of this section.

(vii) ''CAUTION—Hazardous x-rays when open.'' for collateral radiation in excess of the accessible emission limits in Table VI, item 2 of paragraph (d) of this section.

(7) *Labels for defeatably interlocked protective housings.* For each laser product, labels shall be provided for each defeatably interlocked (as described in paragraph (f)(2)(iv) of this section) portion of the protective housing which is designed to be displaced or removed during operation, maintenance, or service, and which upon interlock defeat could permit human access to laser or collateral radiation in excess of the limits of Class I or Table VI. Such labels shall be visible on the product prior to and during interlock defeat and in close proximity to the opening created by the removal or displacement of such portion of the protective housing, and shall include the wording:

(i) ''CAUTION—Laser radiation when open and interlock defeated. DO NOT STARE INTO BEAM.'' for Class II accessible laser radiation.

(ii) ''CAUTION—Laser radiation when open and interlock defeated. DO NOT STARE INTO BEAM OR VIEW DIRECTLY WITH OPTICAL INSTRUMENTS.'' for Class IIIa accessible laser radiation with an irradiance less than or equal to 2.5×10^{-3} W cm^{-2}.

(iii) ''DANGER—Laser radiation when open and interlock defeated. AVOID DIRECT EYE EXPOSURE.'' for Class IIIa accessible laser radiation when an irradiance greater than 2.5×10^{-3} W cm^{-2}.

(iv) ''DANGER—Laser radiation when open and interlock defeated. AVOID DIRECT EXPOSURE TO

BEAM.'' for Class IIIb accessible laser radiation.

(v) ''DANGER—Laser radiation when open and interlock defeated. AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION.'' for Clas IV accessible laser radiation.

(vi) ''CAUTION—Hazardous electromagnetic radiation when open and interlock defeated.'' for collateral radiation in excess of the accessible emission limits in Table VI. item 1 of paragraph (d) of this section.

(vii) ''CAUTION—Hazardous x-rays when open and interlock defeated.'' for collateral radiation in excess of the accesible emission limits in Table VI. item 2 of paragraph (d) of this section.

(8) *Warning for visible and/or invisible radiation.* On the labels specified in this paragraph, if the laser or collateral radiation referred to is:

(i) Invisible radiation, the word ''invisible'' shall appropriately precede the word ''radiation''; or

(ii) Visible and invisible radiation, the words ''visible and invisible'' or ''visible and/or invisible'' shall appropriately precede the word ''radiation.''

(iii) Visible laser radiation only, the phrase ''laser light'' may replace the phrase ''laser radiation.''

(9) *Positioning of labels.* All labels affixed to a laser product shall be positioned so as to make unnecessary, during reading, human exposure to laser radiation in excess of the accessible emission limits of Class I radiation or the limits of collateral radiation established to Table VI of paragraph (d) of this section.

(10) *Label specifications.* Labels required by this section and § 1040.11 shall be permanently affixed to, or inscribed on, the laser product, legible, and clearly visible during operation, maintenance, or service, as appropriate. If the size, configuration, design, or function of the laser product would preclude compliance with the requirements for any required label or would render the required wording of such label inappropriate or ineffective, the Director, Office of Compliance (HFZ–300), Center for Devices and Radiological Health, on the Director's own initiative or upon written application by the manufacturer, may approve alternate means of providing such label(s) or alternate wording for such label(s) as applicable.

(h) *Informational requirements*—(1) *User information.* Manufacturers of laser products shall provide as an integral part of any user instruction or operation manual which is regularly supplied with the product, or, if not so supplied, shall cause to be provided with each laser product:

(i) Adequate instructions for assembly, operation, and maintenance, including clear warnings concerning precautions to avoid possible exposure to laser and collateral radiation in excess of the accessible emission limits in Tables I, II-A, II, III–A, III-B, and VI of paragraph (d) of this section, and a schedule of maintenance necessary to keep the product in compliance with this section and § 1040.11.

(ii) A statement of the magnitude, in appropriate units, of the pulse durations(s), maximum radiant power and, where applicable, the maximum radiant energy per pulse of the accessible laser radiation detectable in each direction in excess of the accessible emission limits in Table I of paragraph (d) of this section determined under paragraph (e) of this section.

(iii) Legible reproductions (color optional) of all labels and hazard warnings required by paragraph (g) of this section and § 1040.11 to be affixed to the laser product or provided with the laser product, including the information required for positions 1, 2, and 3 of the applicable logotype (Figure 1 of paragraph (g)(1)(ii) or Figure 2 or paragraph (g)(2)(ii) of this section). The corresponding position of each label affixed to the product shall be indicated or, if provided with the product, a statement that such labels could not be affixed to the product but were supplied with the product and a statement of the form and manner in which they were supplied shall be provided.

(iv) A listing of all controls, adjustments, and procedures for operation and maintenance, including the warning ''Caution—use of controls or adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure.''

(v) In the case of laser products other than laser systems, a statment of the compatibility requirements for a laser energy source that will assure compliance of the laser product with this section and § 1040.11.

(vi) In the case of laser products classified with a 7 millimeter diameter aperture stop as provided in paragraph (e)(3)(i) of this section, if the use of a 50 millimeter diameter aperture stop would result in a higher clsssification of the product, the following warning shall be included in the user information: ''CAUTION—The use of optical instruments with this product will increase eye hazard.''

(2) *Purchasing and servicing information*. Manufacturers of laser products shall provide or cause to be provided:

(i) In all catalogs, specification sheets, and descriptive brochures pertaining to each laser product, a legible reproduction (color optional) of the class designation and warning required by paragraph (g) of this section to be affixed to that product, including the information required for positions 1, 2, and 3 of the applicable logotype (Figure 1 of paragraph (g)(1)(ii) or Figure 2 of paragraph (g)(2)(ii) of this section).

(ii) To servicing dealers and distributors and to others upon request at a cost not to exceed the cost of preparation and distribution, adequate instructions for service adjustments and service procedures for each laser product model, including clear warnings and precautions to be taken to avoid possible exposure to laser and collateral radiation in excess of the accessible emission limits in Tables I, II–A, II, III–A, III–B, and VI of paragraph (d) of this section, and a schedule of maintenance necessary to keep the product in compliance with this section and § 1040.11; and in all such service instructions, a listing of those controls and procedures that could be utilized by persons other than the manufacturers or the manufacturer's agents to increase accessible emission levels of radiation and a clear description of the location of displaceable portions of the protective housing that could allow human access to laser or collateral radiation in excess of the accessible emission limits in Tables I, II–A, II, III–A, III–B, and VI of paragraph (d) of this section. The instructions shall include protective procedures for service personnel to avoid exposure to levels of laser and collateral radiation known to be hazardous for each procedure or sequence of procedures to be accomplished, and legible reproductions (color optional) of required labels and hazard warnings.

(i) *Modification of a certified product.* The modification of a laser product, previously certified under § 1010.2, by any person engaged in the business of manufacturing, assembling, or modifying laser products shall be construed as manufacturing under the act if the modification affects any aspect of the product's performance or intended function(s) for which this section and § 1040.11 have an applicable requirement. The manufacturer who performs such modification shall recertify and reidentify the product in accordance with the provisions of §§ 1010.2. and 1010.3.

[The information collection requirements contained in paragraph (a)(3)(ii) were approved by the Office of Management and Budget under control number 0910–0176]

[50 FR 33688, Aug. 20, 1985; 50 FR 42156, Oct. 18, 1985]

§ 1040.11 Specific purpose laser products.

(a) *Medical laser products.* Each medical laser product shall comply with all of the applicable requirements of § 1040.10 for laser products of its class. In addition, the manufacturer shall:

(1) Incorporate in each Class III or IV medical laser product a means for the measurement of the level of that laser radiation intended for irradiation of the human body. Such means may have an error in measurement of no more than 20 percent when calibrated in accordance with paragraph (a)(2) of this section. Indication of the measurement shall be in International System Units. The requirements of this paragraph do not apply to any laser radiation that is all of the following:

(i) Of a level less than the accessible limits of Class IIIa; and

(ii) Used for relative positioning of the human body; and

(iii) Not used for irradiation of the human eye for ophthalmic purposes.

(2) Supply with each Class III or IV medical laser product instructions specifying a procedure and schedule for

附件5

Laser Products – Conformance with IEC 60825-1, Am. 2 and IEC 60601-2-22; Final Guidance for Industry and FDA

(Laser Notice No. 50)

Document issued on: July 26, 2001

Center for Devices and Radiological Health
CDRH

U.S. Department Of Health and Human Services
Food and Drug Administration
Center for Devices and Radiological Health

Electronic Product Devices Branch
Division of Enforcement III
Office of Compliance

Preface

Public Comment

For 90 days following the date of publication in the Federal Register of the notice announcing the availability of this guidance, comments and suggestions regarding this document should be submitted to the Docket No. assigned to that notice, Dockets Management Branch, Division of Management Systems and Policy, Office of Human Resources and Management Services, Food and Drug Administration, 5630 Fishers Lane, Room 1061, (HFA-305), Rockville, MD 20852. Such comments will be considered when determining whether to amend the current guidance.

After 90 days following the date of publication in the Federal Register of the notice announcing the availability of this guidance, comments and suggestions may be submitted at any time for Agency consideration to Dockets Management Branch. Comments may not be acted upon by the Agency until the document is next revised or updated. For questions regarding the use or interpretation of this guidance contact Jerome E. Dennis at (301) 594-4654, ext. 135, or by electronic mail at jxd@cdrh.fda.gov.

Additional Copies

Additional copies are available from the Internet at: http://www.fda.gov/cdrh/comp/guidance/1346.pdf, or CDRH Facts-On-Demand. In order to receive this document via your fax machine, call the CDRH Facts-On-Demand system at 800-899-0381 or 301-827-0111 from a touch-tone telephone. Press 1 to enter the system. At the second voice prompt, press 1 to order a document. Enter the document number 1346 followed by the pound sign (#). Follow the remaining voice prompts to complete your request.

Guidance on Laser Products – Conformance with IEC 60825-1, Am. 2 and IEC 60601-2-22 (Laser Notice No. 50)

This document is intended to provide guidance. It represents the Agency's current thinking on this topic. It does not create or confer any rights for or on any person and does not operate to bind the Food and Drug Administration (FDA) or the public. An alternative approach may be used if such approach satisfies the requirements of the applicable statute and regulations.

Purpose

This guidance describes the conditions under which laser product manufacturers may introduce into United States commerce laser products that comply with the IEC standards 60825-1, as amended, and 60601-2-22. This guidance also describes additional requirements of the CDRH standard and alternate certification statements to be used with such products.

Issue

The Food and Drug Administration's (FDA) Center for Devices and Radiological Health (CDRH) intends to amend its standards for laser products at 21 CFR §1040.10 and §1040.11 to harmonize many of its requirements with those of the IEC 60825-1 and 60601-2-22 standards. Although CDRH began its amendment process in anticipation of the amendment of IEC 60825-1, it is not yet ready to publish an amendment. CDRH has acknowledged the advantages of one set of criteria and requirements worldwide. Amendment 2 to IEC 60825-1 was published in January 2001. As a result, manufacturers distributing products in both the U.S. and countries that require conformance with, or that recognize IEC 60825-1, will have to evaluate the conformance of their products with this standard. This requires them to often change the hazard classification of their products. These manufacturers are requesting relief from CDRH so that they will have to comply with only one laser product radiation safety standard.

Background

Laser products for introduction into commerce in or imported into the United States must:

- Comply with 21 CFR §1040.10 and §1040.11 as applicable,
- Be certified and identified in accordance with 21 CFR §1010.2 and §1010.3, and
- Be reported in accordance with 21 CFR §1002.10.

CDRH has issued notices to laser product manufacturers and importers stating non-objection to:

- Lack of emission indicators or beam attenuators on Class II and Class IIIa systems, and
- Hazard warning labels as specified in IEC 60825-1.

These notices reduced the regulatory burden on both the industry and the agency.

CDRH will not object to conformance with many sections of IEC 60825-1, as amended, and IEC 60601-2-22 as alternatives to comparable sections of 21 CFR §1040.10 and §1040.11. CDRH plans to amend federal regulations for laser products to reflect those sections of the IEC standards. CDRH is also listing sections of its standard that contain requirements to which manufacturers must conform. This action is appropriate because of the numerous requests for relief, the amendment of IEC 60825-1, and the Center's intent to harmonize its requirements with many of those of the IEC standards.

The Least Burdensome Approach

We believe we should consider the least burdensome approach in all areas of regulated products. This guidance reflects our careful review of the relevant scientific and legal requirements and what we believe is the least burdensome way for you to comply with those requirements. However, if you believe that an alternative approach would be less burdensome, please contact us so we can consider your point of view. You may send your written comments to the contact person listed in the preface to this guidance or to the CDRH Ombudsman. Comprehensive information on CDRH's Ombudsman, including ways to contact him, can be found on the Internet at http://www.fda.gov/cdrh/resolvingdisputes/ombudsman.html.

Guidance

Effective immediately, and until the effective date(s) of any amendments of the Federal regulations affecting laser products, CDRH will not object to conformance with the comparable sections of IEC 60825-1, as amended by Amendment 2 of January 2001 in lieu of conformance with the following sections of 21 CFR §1040:

1040.10(b)	Definitions
1040.10(c)(1)	Classification
1040.10(d)	Accessible emission limits
1040.10(e)	Tests for determination of compliance
1040.10(f)(1)	Protective housing
1040.10(f)(2)	Safety interlocks
1040.10(f)(3)	Remote Interlock connector
1040.10(f)(4)	Key control
1040.10(f)(5)	Laser radiation emission indicator
1040.10(f)(6)	Beam attenuator
1040.10(f)(7)	Location of controls
1040.10(f)(8)	Viewing optics
1040.10(f)(9)	Scanning safeguard
1040.10(g)	Labeling requirements
1040.10(h)(1)	User information

1040.11(a)	Medical laser products

CDRH intends to harmonize the requirements of these sections with those of the IEC standards.

However, laser products must conform to the following sections of the CDRH standards:

1010.2	Certification
1010.3	Identification
1010.4	Variances
1040.10(a)	Applicability
1040.10(c)(2)	Removable laser systems
1040.10(f)(10)	Manual reset mechanism
1040.10(h)(2)	Purchasing and servicing information
1040.10(i)	Modification of a certified product
1040.11(b)	Surveying, leveling and alignment laser products
1040.11(c)	Demonstration laser products

CDRH intends to retain these requirements even if they differ from the IEC. They are either beyond the scope of the IEC standard, are sufficiently different, or are not normative and included as recommendations in the User's Guide section of the IEC standard.

In using this guidance, manufacturers should:

1. Use the following modified statement of compliance on the certification label: "Complies with FDA performance standards for laser products except for deviations pursuant to Laser Notice No. 50, dated (Insert date of this guidance.)" or "Complies with 21 CFR 1040.10 and 1040.11 except for deviations pursuant to Laser Notice No. 50, dated (Insert date of this guidance.);" and
2. Submit product reports or supplemental reports to describe changes to products in accordance with this guidance.

The effectiveness of this guidance will end on the effective date(s) of any amendments to the Federal regulations applicable to laser products under Chapter 1, Subchapter J of Title 21 of the Code of Federal Regulations.

Getting More Information

You can get more information about our requirements for lasers from our electronic product radiation control web page at http://www.fda.gov/cdrh/radhlth/.

If you have questions about this guidance, contact Jerome Dennis, CDRH, Office of Compliance (HFZ-342), 2094 Gaither Rd., Rockville, MD 20850, FAX 301-594-4672, or e-mail jxd@cdrh.fda.gov.

Sincerely yours,

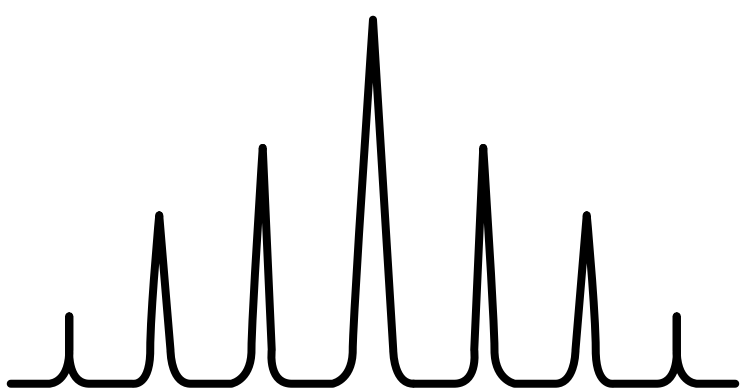
Larry D. Spears

Larry D. Spears
Acting Director
Office of Compliance
Center for Devices and Radiological Health

附件6

Accurate Characterization of Source Spectra Using an Optical Spectrum Analyzer

Application Note 1550-5



Agilent Technologies

Innovating the HP Way

An optical spectrum analyzer performs power versus wavelength measurements, a very useful tool for characterizing broadband sources such as light emitting diodes (LEDs) and semiconductor lasers. This application note will give a descriptive overview of how each light source emits light and how the important parameters can be measured using an optical spectrum analyzer (OSA).

Source overview

This section will give a brief overview of lasers and LED sources.

Background

Laser is an acronym for Light Amplification by the Stimulated Emission of Radiation. Let us look at what each term means and how they all work together to produce light.

Lasers are monochromatic sources, which in theory means they produce light at one single wavelength, but in practice there is a narrow wavelength range in which light is emitted.

Coherence is an important property of lasers. Lightwaves are coherent if they are all in phase with each other. The peaks and valleys of coherent lightwaves are aligned (Figure 1a); the peaks and valleys of incoherent lightwaves are not (Figure 1b). In order to have coherent light, all the lightwaves must have the same wavelength.

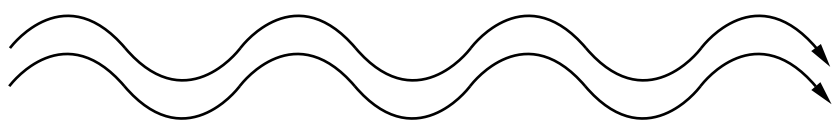


Figure 1a. Coherent waves

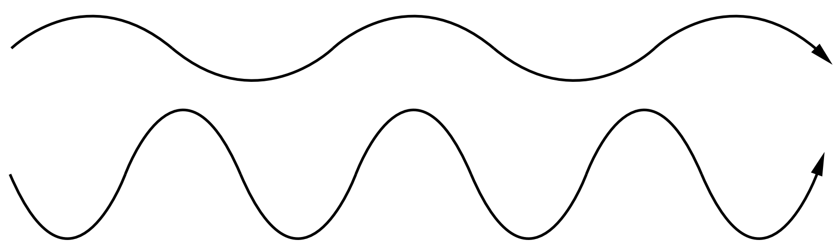


Figure 1b. Incoherent waves

There are many different types of lasers, but for the purposes of this application note we will look at lasers used in the fiber-optic communication technology, mainly semiconductor lasers. They are used because they are very small in size, yet can produce a few milliwatts of light power. Another important feature is that by varying their current, emitted light power can be controlled.

Theory of operation

Semiconductor conductivity is determined by the number of charge carriers available to conduct electric current, conductivity ranges between that of a good conductor (such as metal) and that of an insulator (such as glass). The electrons of a conductor are free to move by way of electric current, while the electrons of an insulator cannot. By adding impurities to semiconductor material we are able to influence its electrical properties and create what is referred to as p-type and n-type regions. A p-type region is doped with impurities that have fewer electrons than atoms. Therefore, “holes”, where there is room for electrons, are created. An n-type region is where impurities are added such that there is an excess of electrons. The excess holes in the p-type and electrons in the n-type regions play an important role in the process of light emission.

Figure 2 demonstrates the two energy bands that exist in semiconductor material. The conduction band is at a higher energy level where electrons can freely move about. The valence band is where the electrons form bonds with adjacent atoms. The distance between the two is called the band gap. Electrons must release energy that exceeds the band gap when they drop from the conduction band down to valence band. This energy is released as a photon of light.

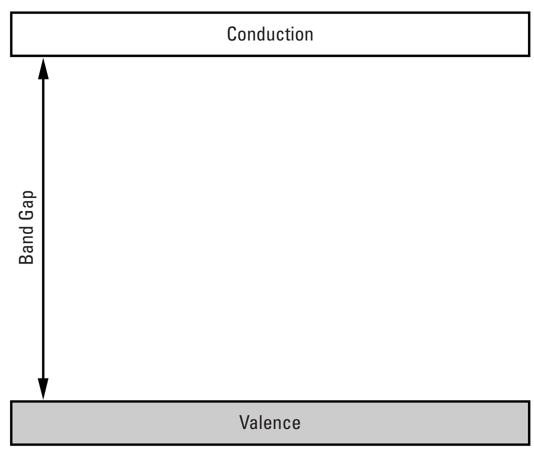


Figure 2. Conduction band and valence band

The wavelength of light released is proportional to the band gap energy by the following formula:

$$E_{\text{band gap}} = h \times \nu_{\text{band gap}}$$

where:
h = Plank’s constant = 6.62 x 10^{-34} = J-s
ν = frequency of the photon released
E = energy of the band gap

If we substitute wavelength for frequency, plug in the value for Plank’s constant and express the energy in electron-volts, we have:

$$E_{\text{band gap}} = \frac{1.24\ \mu\text{m}}{\lambda}$$

This formula helps illustrate the dependency of the wavelength of photons and the band gap energy of the material.

Now let us take a look at how this junction of p-type and n-type material can produce light. When we forward bias the junction by applying a negative voltage to the n-type material and a positive voltage to the p-type material the following happens: Electrons from the n-type section recombine with holes in the p-type material, dropping into the valence band and releasing their energy at the junction. In materials such as GaAs this energy is primarily released as light (Figure 3).

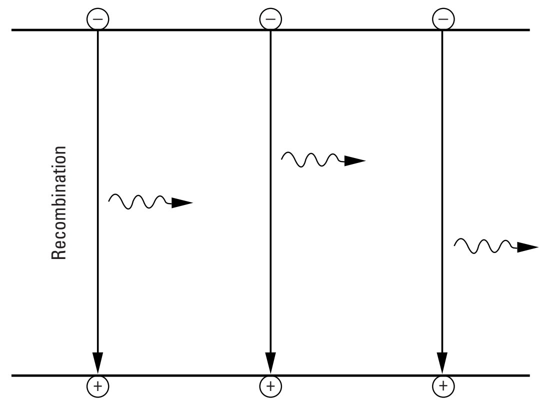


Figure 3. An electron releases it's energy as light and recombines with a "hole".

This light emission from the recombination of electrons and holes is the basic mechanism behind LEDs and lasers. In the case of an LED, a forward biased junction emits light by way of electron/hole pair recombination. The junction of a basic LED emits light in every direction as shown in Figure 4.

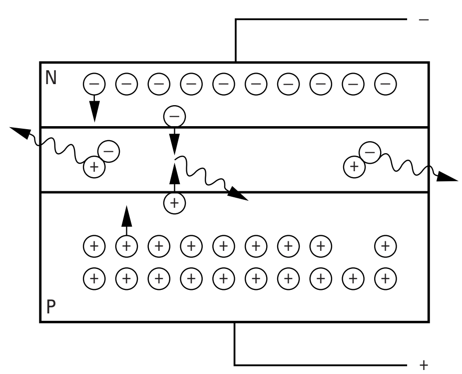


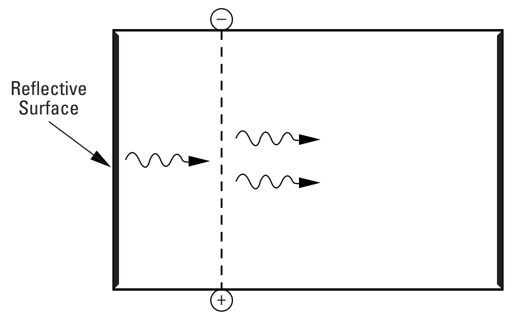
Figure 4. An LED emits light in every direction.

LEDs do not generate light in a manner as focused as lasers. They produce light by way of spontaneous emission and not stimulated emission.

Lasers are closely related to LEDs. They each:
- generate light by recombining electrons and holes
- have light output that is proportional to the drive current
- have an output wavelength that depends on the material's band gap

In spontaneous emission light is generated in all directions. If we use two reflective materials (e.g. mirrors) we are able to confine the photons in a region, thus stimulating other electrons to release their energy as light, in turn producing more photons. Therefore we generate light by way of stimulated emission. Due to the process of stimulated emission, laser diodes emit basically monochromatic light. The type of semiconductor material used determines the peak wavelength. For example, Gallium-Aluminum-Arsenide (GaAlAs) emits light at a peak wavelength of 850 nm. As the light reflects between the mirrors, the photons of a given wavelength are amplified by adding up constructively. The following formula demonstrates the possible wavelengths produced in a laser cavity:

$$\lambda = 2*L*n/m$$



Where
n = the refractive index in the cavity
m = an integer
L = the cavity length (mirror spacing)
λ = peak wavelength

If the laser cavity is much longer than the wavelength, which is usually the case, more than one wavelength will be emitted (see Figure 5). Looking at the spectrum (amplitude versus wavelength) of lasers, each individual spectral laser line is referred to as one mode. This type of laser is known as a Multiple Longitudinal Mode laser (MLM). An example of a MLM type laser is the Fabry-Perot (FP) laser. When there are multiple longitudinal modes, the source has a greater spectral width. Recall from our discussion about coherence of sources, the greater the spectral width of the source is, the less coherent the source becomes.

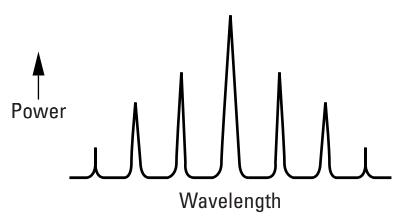


Figure 5a. Wavelengths in multiple longitude modes

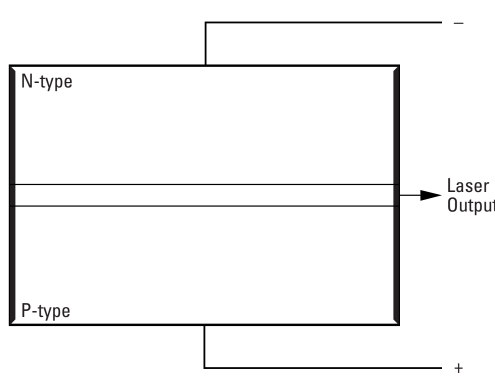


Figure 5b. Forward bias junction of a Fabry-Perot laser

Some applications require a laser to emit light only at a single narrow wavelength range (e.g. Dense Wavelength Division Multiplexing (DWDM) application). One approach to limit laser oscillation to a single longitudinal mode, is the distributed feedback laser (DFB). DFB lasers contain a diffraction grating that scatters light back into the active region. Feedback from the grating causes interference effects that allow oscillation only at the wavelengths at which the interference is constructive, reinforcing the generated light (Figure 6).

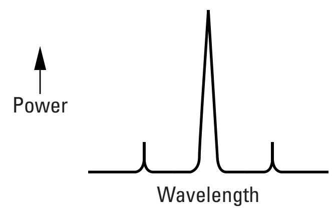


Figure 6a. Single longitudinal mode

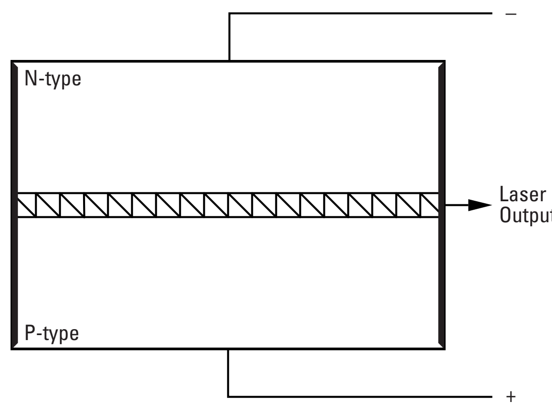


Figure 6b. A forward bias junction of a DFB laser

Summary of typical specification of the sources discussed is illustrated in Table 1.

Table 1.

	LED	Fabry-Perot	DFB
Wavelength	780, 850, 1300 nm	850 or 1310 nm	1550 nm
Total power	Few μW	Few mW	3 to 50 mW
Spectral width	30 to 100 nm	3 to 20 nm	0.08 to 0.8 pm

LED Measurements

There are many parameters of LEDs that are commonly measured. These parameters can be automatically measured as shown in Figure 7.

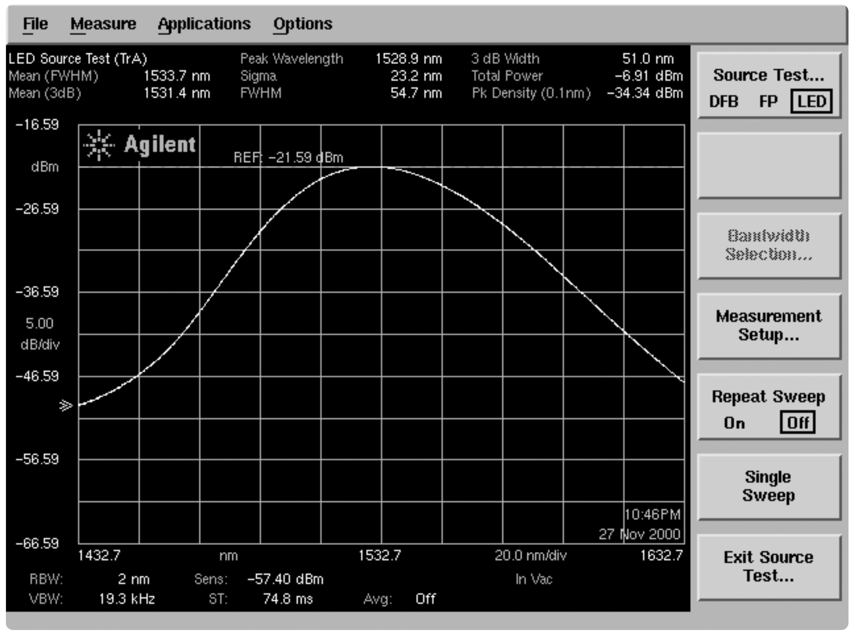


Figure 7. Agilent 86140B optical spectrum analyzer source application LED measurement

Total power

When the OSA measures an LED source, the spectral width of this source is much wider than the OSA resolution bandwidth (RBW) used. The OSA trace points represent spectral density (mW/nm) and not absolute power. Over wide wavelength ranges, the ratio of OSA slit width/wavelength also causes the effective RBW to change. Therefore the integration formula takes both dependencies into account by using internal calibration data.

$$\text{Total power, } P_o = \sum_{i=1}^{n} p_i \left(\frac{\text{trace point spacing}}{\text{RBW}}\right)$$

where:

n is the number of trace points

p_i is the power of a single trace point

3 dB width

The 3 dB width is determined by finding the peak of the LED spectrum, and dropping down 3 dB on each side. The spectral width of the LED is determined by the separation of these two points because each has a power spectral density equal to one half the peak power spectral density.

Peak density (1 nm)

The power spectral density normalized to a 1 nm bandwidth of the LED at the peak wavelength is referred to as the peak density. Peak wavelength is the highest trace point and is where the peak of the LED spectrum occurs.

$$\text{Peak Density} = \frac{P_{peak}}{\text{RBW}\ (\lambda_{peak})}$$

Sigma

Sigma is the RMS value of spectral width of the LED based on a Gaussian distribution. The value of sigma (σ) is calculated by the following formula:

$$\text{Sigma} = \sigma = \sqrt{\sum_{i=1}^{n} \frac{p_i}{P_o} \left(\frac{\text{trace point spacing}}{\text{RBW}} \right) (\lambda_i - \bar{\lambda})^2}$$

where:

$\bar{\lambda}$ is mean wavelength (FWHM) as defined below.

λ_i is the wavelength of a single trace point.

p_i is the power of a single trace point.

P_o is total power as defined.

Mean wavelength

This wavelength represents the center of mass for all the trace points. The total power and wavelength of each trace point is used to calculate the mean wavelength.

$$\bar{\lambda} = \sum_{i=1}^{n} \frac{p_i}{P_o} \left(\frac{\text{trace point spacing}}{\text{RBW}} \right) \lambda_i$$

Center wavelength

Center wavelength is the average of two wavelengths determined in the 3 dB width measurements. Typically the values of mean wavelength and center wavelength are similar.

Full Width Half Max (FWHM)

FWHM describes the spectral width of the half power points of the LED. Half power points are where power spectral density is one half of the peak amplitude. FWHM value and the 3 dB width values are typically very close to one another. This parameter is calculated using sigma value.

FWHM = 2.355 * σ

See Appendix 1.

Fabry-Perot Measurements

Many of the commonly measured parameters of Fabry-Perot lasers will be discussed in this section. The optical spectrum analyzer has an automatic measurement routine for Fabry-Perot lasers. The results from the Fabry-Perot laser measurement routine are shown in Figure 8. The following parameters are often of interest and are measured by the automatic routine.

Measurement attributes are calculated using the entire set of trace points in order to provide more repeatable results. This is particularly useful for devices that exhibit significant levels of fluctuation in the distribution of optical energy among the spectral modes.

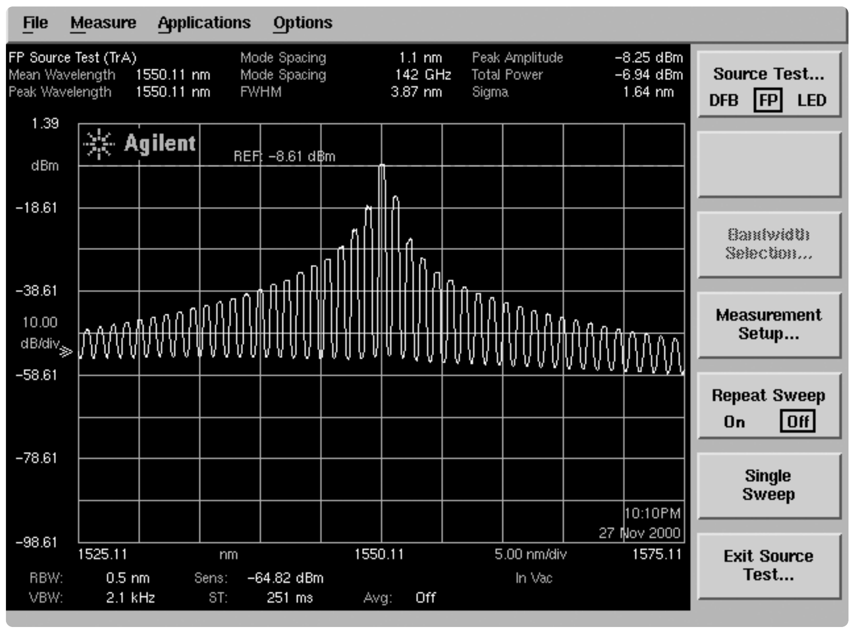


Figure 8. Agilent 86140B optical spectrum analyzer source application Fabry-Perot measurement

Total power
Total power is the summation of the power at each trace point, normalized by the ratio of the trace point spacing and the resolution bandwidth.

$$\text{Total power} = \sum_{i=1}^{n} p_i \left(\frac{\text{trace point spacing}}{\text{RBW}} \right)$$

Mean wavelength
Mean wavelength represents the center of mass of the trace points, normalized by a ratio of the trace point spacing and the resolution bandwidth. The power and wavelength of each trace point are used to calculate the mean (FWHM) wavelength.

$$\bar{\lambda} = \sum_{i=1}^{n} \frac{p_i}{P_o} \left(\frac{\text{trace point spacing}}{\text{RBW}} \right) \lambda_i$$

Sigma
Sigma is the RMS value of spectral width of the LED based on a Gaussian distribution. The power and wavelength of each spectral component is used to calculate mean wavelength.

$$\text{Sigma} = \sigma = \sqrt{\sum_{i=1}^{n} \frac{p_i}{P_o} \left(\frac{\text{trace point spacing}}{\text{RBW}} \right) (\lambda_i - \bar{\lambda})^2}$$

where:

$\bar{\lambda}$ is mean wavelength (FWHM).

λ_i is the wavelength of a single trace point.

p_i is the power of a single trace point.

P_o is total power as defined.

FWHM
Full Width Half Max describes the spectral width of the half power points of the laser, assuming a continuous, Gaussian power distribution. The half power points are where power spectral density is one half of the peak amplitude. This parameter is be calculated using the sigma value.

$$\text{FWHM} = 2.355 * \sigma$$

Mode spacing (in nm)
Mode spacing is the *average* wavelength spacing between the individual spectral components of the Fabry-Perot laser.

Mode spacing (in GHz) is the average frequency between the individual spectral components of the FP laser.

Peak amplitude and peak wavelength
The peak amplitude is the power level of the peak spectral component or mode of the Fabry-Perot laser. The wavelength at which the peak amplitude occurs is the peak wavelength.

Distributed feedback laser measurements

The results from the DFB laser automatic measurement routine performed by an Agilent optical spectrum analyzer are shown in Figure 9. The following parameters are often of interest and are measured automatically.

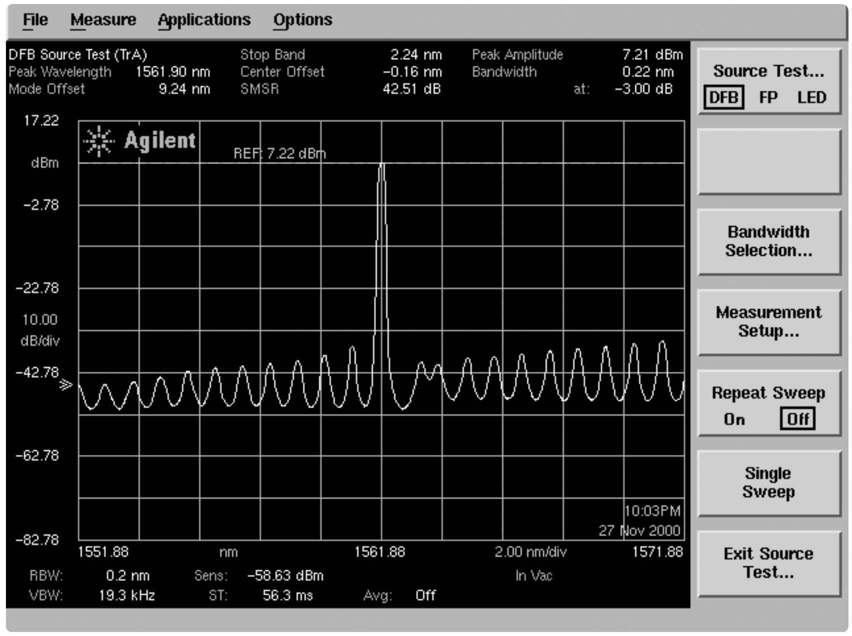


Figure 9. Agilent 86140B optical spectrum analyzer source application DFB laser measurement

Peak amplitude and peak wavelength
The power level of the main spectral component or the main mode of the laser is the peak amplitude. The wavelength at which the main mode of the laser occurs is the peak wavelength.

Side mode suppression ratio (SMSR)
SMSR is the amplitude difference between the main mode and the largest side mode.

Mode offset
Mode offset is a measure of the wavelength separation between the main mode and the largest side mode, within current trace span. Negative values indicate the next highest mode lies to the left of the main mode and positive values indicate the next highest mode lies to the right of the main mode.

Stop band
The wavelength spacing between the upper and lower side modes adjacent to the main mode is referred to as the stop band.

Center offset
This is a measurement that indicates how well the main mode is centered in the stop band. This value equals the wavelength of the main mode minus the mean of the upper and lower stop band component wavelengths.

Bandwidth
This is the main spectral component of the DFB laser. Due to the narrow linewidth of most DFB lasers, the result of this measurement for an unmodulated laser is limited by the resolution bandwidth of the optical spectrum analyzer.

Chirp and linewidth are important measurements for lasers, but they are beyond the scope of this application note. For more information, please refer to “Agilent Lightwave Signal Analyzers, Measure Relative Intensity Noise” product note, publication number 5091-2196E and “Agilent Lightwave Signal Analyzer Application Note”, publication number 5954-9137E for Chirp and line width measurement techniques.

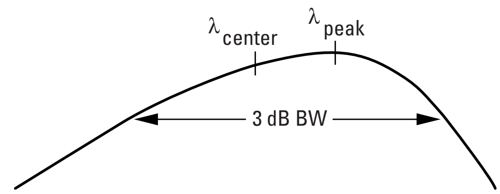
Conclusion

There are many important parameters to consider when designing and testing light sources. As we discussed, an optical spectrum analyzer is the best, preferred and most popular tool for analyzing the spectrum of light sources. These parameters can be measured automatically using the source application of an Agilent 8614xB optical spectrum analyzer.

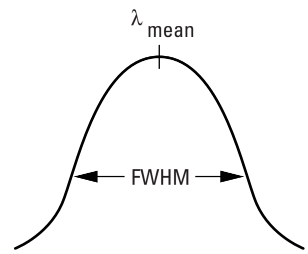
Appendix I.

FWHM measurement assumes a Gaussian shaped trace as follow:

Trace (measured)



Gaussian



References

"Understanding LASERS", by Jeff Hecht, second edition, published by IEEE PRESS, ISBN 0-7803-1005-5.

"Understanding Fiber Optics", by Jeff Hecht, third edition, published by Prentice Hall, ISBN 0-13-956145-5.

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附件7

Certificate of Completion

We, Japan Quality Assurance Organization, hereby award this certificate to **Mr. Chui-Hsin Chiu** of BUREAU OF STANDARDS, METROLOGY AND INSPECTION MINISTRY OF ECONOMIC AFFAIRS for completing the following training course.

Training Course: Practical Study of Evaluation Method for LEDs
Duration: April 20, 2009 ～ April 23, 2009
Training Contents:
1. The measurement method of IEC60825-1:2001 clause 9 for LEDs.
2. The outline of measurement method of IEC62471:2006 for visible LEDs.
3. The outline of measurement facilities the standard needs.
4. The interpretation of the definition needed for measurement of LEDs.
5. The important point for checking JQA's Laser Measurement Report.

財団法人 日本品質保証機構
Japan Quality Assurance Organization
21-25, Kinuta 1-Chome, Setagaya-Ku, Tokyo, Japan

M. Takahashi
Masaaki Takahashi, Director
SAFETY & EMC Center
Date: April 23, 2009

389-090003

表1．関連標準類の一覧

Table 1.　related Standards list

光学測定関係	
CIE TC2-45 CIE 127-2007	Measurement of LEDs
IES LM-79	IESNA Electrical and Photometric Measurements of SSL Products
IESNA LM-80	Approved Method for Measuring Lumen Maintenance of LED Light Source
CIE.TC2-46	CIE/ISO LED intensity measurements
CIE TC2-50	Optical Properties of LED arrays
CIE TC2-58	Luminance and radiance of LEDs
測色関係	
ANSI C78.377-2008	Chromaticity of SSL Products
CIE TC1-62 1 77-2007	Colour Rendering of White LED Light source
CIE TC1-69	Colour Quality Scale（new）
目に対する安全	
IES RP-27	Photobiological Safety
IEC 60825-1-2001	Safety of Laser product - to be superseded by new documents
CIE S009	Photobiological Safety
IEEE P1789	Recommended Practices of Modulating Current in High Brightness LEDs for Mitigating Health Risks to Viewers
安全関係	
ANSI C82.SSL1	Power Supply
ANSI C78.09-82	Fixture Safety Specification
FCC 47 CFR Part 15	Radio Frequency Devices
IEC SC34A 62031:2008	LED modules - Safety
IEC SC34C 61347-2-13	Lamp Controlgear - Part 2-13 DC or AC controlgear for LED modules
IEC SC34A<TBD>	LED Lamps > 50V - Safety Specifications
UL8750	LED Light Sources for Use in Lighting Products
専門用語	
IES RP-16	Nomenclature and Definitions - Addendum A : SSL Definition
IEC SC34A - TS62504	Terms and Definitions for LEDs and LED Modules in General Lighting
取付け・互換	
ANSI SSL2 LSD-45	Sockets & Interconnects
ANSI C82.04	Driver Safety Circuitry
新しい標準	
IES TM-21	a method for extrapolating longer-term LED performance based on LM-80 test results

JELMA 24 April, 2009

Standardizing Activity about LED for Lighting (JIS : Japan Industrial Standard)

○ Measurement

- JIS C 8152: Measuring methods of white light emitting diode for general lighting. (Published)

○ Safety

- JIS C 8147-2-13: Lamp control gear – Part 2-13: Particular requirements for DC or AC supplied electronic control gear for LED modules. (Published)
- JIS C 8154: LED modules for general lighting – Safety specifications. (Published)
- JIS C 8156: Self-ballasted LED lamps for general lighting services > 50V – Safety specifications. (will be published)

○ Performance

- JIS C 8153: DC or AC supplied electronic control gear for LED modules – Performance requirements. (Published)
- TS C 8153: White light emitting diode devices for general lighting – Performance specifications. (Published)

Transitive TS→JIS ↓

- JIS C 8155: LED modules for general lighting – Performance requirements. (will be published)
- JIS C 8157: Self-ballasted LED lamps for general lighting services > 50V – Performance requirements. (will be published)

○ Product

- JIS C 8158: Self-ballasted LED lamps for general lighting purposes. (will be published)

平成19～23年度　(社)日本電球工業会JIS制定／改正計画案〔LED関連規格〕

2009年 4月 24日

○：公募申請日　●：発行日　◎：発行予定日

担当委員会	JIS番号 制定年	規格名称	H19年度 2007	H20年度 2008	H21年度 2009	H22年度 2010	H23年度 2011	H24年度 2012	IEC Pub.#	JIS対応版	最新版	改正進行中
			4月 8月 12月	4月 8月 12月	4月 8月 12月	4月 8月 12月	4月 8月 12月	4月 8月 12月				
照明用LED製品仕様分科会 (原案作成中)	C8156 (2011)	一般照明用 電球形LEDランプ(電源電圧50V超) 一安全仕様		○ H20/10末	JIS原案作成 H21年度公募(区分A)	◎ H23/3月(予)			62560 Ed. 1 (CDV待ち段階)			
	C8157 (2012)	一般照明用 電球形LEDランプ(電源電圧50V超) 一性能要求事項			○ H21/10末	JIS原案作成 H22年度公募(区分A)	◎ H24/3月(予)		62612 Ed. 1 (NP段階)			
	C8158 (2012)	一般照明用 電球形LEDランプ(電源電圧50V超)〔製品規格〕←JISマーク表示規格			○ H22/02末	JIS原案作成 H22年度公募(区分B)		◎ H24/7月(予)	JISマーク表示規格よって対応IEC規格なし			
	C8154 (2009)	一般照明用 LEDモジュール 一安全仕様	JIS原案作成 H19年度公募(区分A)	JIS制定 ● H21/3/20					62031	Ed. 1	Ed. 1	Ed. 1 A1 (CD)
	C8155 (2010)	一般照明用 LEDモジュール 一性能要求事項 (TS C 8153⇒JIS化)		○ H20/06末	JIS原案作成 H20年度公募(区分C)	◎ H22/11月(予)			(未発行)	—	—	—
電子トランス分科会	C8147-2-13 2008	ランプ制御装置―第2-13部：LEDモジュール制御装置の個別要求事項		JIS制定 ● H20/10/20					61347-2-13	Ed. 1	Ed. 1	なし
	C8153 (2009)	LEDモジュール用制御装置－性能要求事項	JIS原案作成 H19年度公募(区分A)	JIS制定 ● H21/3/20					62384	Ed. 1	Ed. 1	Ed. 1 A1 (CDV)
一般照明用白色LED光源測光方法通則JIS制定原案作成委員会	C8152 (2007)	照明用白色発光ダイオード（LED）の測光方法	JIS制定 ● H19/7/20									

2.1 電気特性についての規格・試験方法

2.1.1 順電流 （規定の条件下で、規定の順電圧を印加した際に生じる電流）

(1) JIS C 5951-1997	光伝送用発光ダイオード測定方法	6.1 順電流(I_f)
(2) EIAJ ED-4911 1993	発光ダイオード測定方法	6.3 順電流(I_F)測定

2.1.2 順電圧 （規定の条件下で、規定の順電流を流した際に生じる電圧）

(1) JIS C 7036-1985	発光ダイオード測定方法(表示用)	8.1 順電圧(V_F)
(2) JIS C 5951-1997	光伝送用発光ダイオード測定方法	6.2 順電流(V_f)
(3) EIAJ ED-4911 1993	発光ダイオード測定方法	6.1 順電流(V_F)測定
(4) CIE127-1997	Measurement of LEDs	2.2.3 Forward voltage
(5) CIE127.2(4th Draft) 1997	Measurement of LEDs	2.2.4 Forward voltage

2.1.3 逆電流 （規定の条件下で、規定の逆電圧を印加した際に生じる電流）

(1) JIS C 7036-1985	発光ダイオード測定方法(表示用)	8.2 逆電流(I_R)
(2) JIS C 5951-1997	光伝送用発光ダイオード測定方法	6.3 逆電流(I_r)
(3) EIAJ ED-4911 1993	発光ダイオード測定方法	6.4 逆電流(I_R)測定

2.1.4 逆電圧 （規定の条件下で、規定の逆電流を流した際に生じる電圧）

(1) JIS C 5951-1997	光伝送用発光ダイオード測定方法	6.4 逆電圧(V_r)
(2) EIAJ ED-4911 1993	発光ダイオード測定方法	6.2 逆電圧(V_R)測定

2.1.5 端子間容量 （規定のバイアスを印加した場合のLEDの端子間容量）

(1) JIS C 5951-1997	光伝送用発光ダイオード測定方法	6.5 端子間容量
(2) EIAJ ED-4911 1993	発光ダイオード測定方法	6.5 端子間容量(C_t)測定

2.1.6 応答時間 （規定の動作条件下で指定の順方向パルスを印加した際にLEDから放出された光を電気信号に変換した際の、立上り時間、立下り時間、遅延時間）

(1) JIS C 5951-1997	光伝送用発光ダイオード測定方法	6.14 応答時間
(2) EIAJ ED-4911 1993	発光ダイオード測定方法	6.7 応答時間測定

2.1.7 遮断周波数 （基準周波数に対して周波数応答が－3dbとなる周波数）

周波数応答 （規定の動作条件下で規定の順電流を印加し、規定の周波数の小信号交流電流を重畳した後、LEDから放出された光を電気信号に変換した際の変調光に対応した交流電流と、充分に低い基準周波数に対応する交流電流の商）

(1) JIS C 5951-1997	光伝送用発光ダイオード測定方法	6.15 遮断周波数
(2) EIAJ ED-4911 1993	発光ダイオード測定方法	6.8 周波数応答、遮断周波数(f_c)測定

2.2 光特性についての規格・試験方法

2.2.1 全光束 （光源がすべての方向に放出する光束の総和）

(1) CIE84 1989	The Measurement of Luminous Flux	2.1.1 Luminous flux
(2) CIE127 1997	Measurement of LEDs	6. Measurement of total luminous flux
(3) CIE127.2(4th Draft) 1997	Measurement of LEDs	6.1.1 Total luminous flux 6.4.1 Total luminous flux measurement
(4) EIAJ ED-4911 1993	発光ダイオード測定方法	2.3(4) 測光量測定用語とその定義　光束 6.9 光束測定
(5) JEL311 2004	照明用白色LED測光方法通則	3.5 LEDの全光束 8 光束測定

2.2.2 部分光束 （光源が一部の方向に放出する光束）

(1) CIE127.2(4th Draft) 1997	Measurement of LEDs	6.1.2 Partial LED Flux 6.4.2 Partial LED Flux measurement
(2) EIAJ ED-4911 1993	発光ダイオード測定方法	2.3(4) 測光量測定用語とその定義　光束
(3) JEL311 2004	照明用白色LED測光方法通則	8 光束測定

附件10

2.2.3 配 光

(光源および照明器具の光度の角度に対する変化または分布)

(1) CIE84 1989	The Measurement of Luminous Flux	4. Calculation to luminous flux from luminous intensity distribution
(2) CIE127 1997	Measurement of LEDs	2.1.1 Spatial distribution 5.4 Measurement of spatial and directional properties
(3) CIE127.2 (4th Draft) 1997	Measurement of LEDs	2.1.1 Spatial distribution 4.4 Measurement of spatial and directional properties
(4) EIAJ ED-4911 1993	発光ダイオード測定方法	6.16 指向特性測定
(5) JIS C 5951 1997	光伝送用発光ダイオード測定方法	6.12 ビーム広がり角
(6) JIS C 7036 1985	発光ダイオード測定方法(表示用)	2.(9) 指向特性 8.5 指向特性

2.2.4 光 度

(光源からある方向に向かう光束の単位立体角当りの割合)

(1) CIE84 1989	The Measurement of Luminous Flux	2.1.2 luminous intensity
(2) CIE127 1997	Measurement of LEDs	5.2.1 luminous intensity
(3) CIE127.2 (4th Draft) 1997	Measurement of LEDs	4.2.1 luminous intensity
(4) EIAJ ED-4910 1995	発光ダイオード	付表1／付表2
(5) EIAJ ED-4911 1993	発光ダイオード測定方法	2.3(6) 光度 6.11 光度測定
(6) JEL 311 2004	照明用白色LED測光方法通則	7.3 発光部の大きいLEDの光度測定
(7) JIS C 7035 1985	発光ダイオード(表示用)	付表1／付表2
(8) JIS C 7036 1985	発光ダイオード測定方法(表示用)	2(5)光度 8.3 光度

2.2.5 輝 度

(発光面上のある点における、その点を含む微小面を通り、ある方向へ向かう光束の、その方向に垂直な面への単位正射影面積当り、単位立体角当りの割合)

(1) CIE84 1989	The Measurement of Luminous Flux	2.1.4 luminance
(2) EIAJ ED-4910 1995	発光ダイオード	付表1／付表2
(3) EIAJ ED-4911 1993	発光ダイオード測定方法	2.3(7) 輝度 6.13 輝度測定

2.2.6 発光スペクトル

(放射の単色成分を波長または周波数の順に並べて表示したもの)

(1) CIE127 1997	Measurement of LEDs	2.1.2 Spectral distribution 7.4 Measurement of the spectral distribution
(2) CIE127.2 (4th Draft) 1997	Measurement of LEDs	2.1.2 Spectral distribution 7.4 Spectral Measurement of LEDs
(3) EIAJ ED-4911 1993	発光ダイオード測定方法	2.1(7) 分光感度 6.14 スペクトル分布、ピーク波長、半値幅測定
(4) JIS C 5951 1997	光伝送用発光ダイオード測定方法	6.10 ピーク発光波長及びスペクトル半値幅
(5) JIS C 7036 1985	発光ダイオード測定方法(表示用)	2(6) 発光スペクトル分布 8.4 ピーク発光波長及びスペクトル半値幅

2.2.7 色 度

(色度座標によって、または主波長もしくは補色主波長と純度との組合せによって定められる色刺激の性質)

(1) CIE127 1997	Measurement of LEDs	7.3 Colorimetric quantities determined from the spectral distribution
(2) CIE127.2 (4th Draft) 1997	Measurement of LEDs	7.3 Colorimetric quantities determined from the spectral distribution
(3) EIAJ ED-4911 1993	発光ダイオード測定方法	6.15 色度測定
(4) JIS Z 8724 1997	色の測定方法―光源色	

2.2.8 相関色温度

(色度座標上で最も近い黒体軌跡上の温度)

(1) JIS Z 8725 1999	光源の分布温度及び色温度・相関色温度の測定方法	5 相関色温度又は色温度の測定方法

2.2.9 演色性評価数

(光源またはイルミナント(照明光)が、それで照明した種々の物体の色の見えに及ぼす効果(その効果は意識的または無意識的にある基準のイルミナントと比較される))

(1) JIS Z 8726 1990	光源の演色性評価方法	6 演色評価数の求め方

2.2.10 主波長（ドミナント波長）

（特定の無彩色刺激と適当な比率で加法混色することによって試料色刺激に等色するような単色光刺激の波長）

(1)CIE127 1997	Measurement of LEDs	7.3.1 Dominant wavelength
(2)CIE127.2(4th Draft) 1997	Measurement of LEDs	7.3.1 Dominant wavelength
(3)EIAJ ED-4911 1993	発光ダイオード測定方法	6.15 色度測定

2.2.11 ピーク発光波長

（規定の動作電流で光出力が最大値となる波長）

(1)CIE127 1997	Measurement of LEDs	7.2.1 Peak wavelength
(2)CIE127.2(4th Draft) 1997	Measurement of LEDs	7.2.1 Peak wavelength
(3)EIAJ ED-4911 1993	発光ダイオード測定方法	6.14 スペクトル分布、ピーク波長、半値幅測定
(4)JIS C 5950 1997	光伝送用発光ダイオード通則	2(11) ピーク発光波長
(5)JIS C 5951 1997	光伝送用発光ダイオード測定方法	6.10 ピーク発光波長及びスペクトル半値幅
(6)JIS C 7035 1985	発光ダイオード（表示用）	付属書2　3 電気・光学的特性
(7)JIS C 7036 1985	発光ダイオード測定方法(表示用)	2(7) ピーク発光波長 8.4 ピーク発光波長及びスペクトル半値幅

2.2.12 内部量子効率

（内部に吸収された電子(量子)の数に対する、内部で発生した光子(量子)の数の比）

2.2.13 外部量子効率

（外部から与えられた電子(量子)の数に対する、外部に放出した光子(量子)の数の比）

2.2.14 発光効率〔光源効率〕

（光源が発する全光束を、その光源の消費電力で除した値）

2.2.15 放射束

（放射として放出されるパワーで、単位時間当たりの放射エネルギーの割合）

(1)EIAJ ED-4911 1993	発光ダイオード測定方法	2.2(2) 放射束 6.10 放射束測定
(2)JIS C 5950 1997	光伝送用発光ダイオード通則	2(6) 光出力
(3)JIS C 5951 1997	光伝送用発光ダイオード測定方法	6.6 光出力 6.7 積分球を用いた光出力

2.2.16 CIE平均化LED光度

（LEDの先端を頂点として、測光軸を頂点からおろした垂線（中心線）とする円錐内の光束を円錐の底面に対応する立体角について平均した光度）

(1)CIE127 199	Measurement of LEDs	5.3 Averaged LED intensity
(2)CIE127.2(4th Draft) 1997	Measurement of LEDs	4.3 Averaged luminous intensity
(3)JEL 311 2004	照明用白色LED測光方法通則	3.4 CIE平均化LED光度（放射強度） 7.1 CIE平均化LED光度

2.3 温度特性についての規格・試験方法

2.3.1 周囲温度

(1)CIE84 1989	The Measurement of Luminous Flux	8.4 Ambient temperature
(2)CIE127 1997	Measurement of LEDs	2.2.4 Ambient temperature
(3)CIE127.2(4th Draft) 1997	Measurement of LEDs	2.2.5 Ambient temperature
(4)EIAJ ED-4910 1995	発光ダイオード	附属書2表1 2.2.2(3) 周囲温度
(5)EIAJ ED-4911 1993	発光ダイオード測定方法	4.1(1) 温度
(6)JEL311 2004	照明用白色LED測光方法通則	6 点灯条件 附属書1　4.1 温度 附属書3　4.4 測定の環境
(7)JIS C 5950 1997	光伝送用発光ダイオード通則	6. 最大定格（備考2） 附属書1表1（注3）
(8)JIS C 5951 1997	光伝送用発光ダイオード測定方法	3. 測定の状態
(9)JIS C 7035 1985	発光ダイオード(表示用)	附属書2表1 附属書3　2.2.2(3) 周囲温度
(10)JIS C 7036 1985	発光ダイオード測定方法(表示用)	4.1 温度

2.4 熱特性についての規格・試験方法

2.4.1 熱特性

(1)EIAJ ED-4911 1993	発光ダイオード測定方法	6.6 接合温度、熱抵抗(R_{th})測定

2.5 寿命についての規格・試験方法

(1) JIS C 5950 1997	光伝送用発光ダイオード通則	付属書2表1 環境試験及び耐久性試験
(2) JEL 311 2004	照明用白色LED測光方法通則	3.7 LEDの寿命 付属書3(参考)LED光源における寿命特性評価方法
(3) JEL 811 2005	照明用白色LEDモジュール安全性要求事項	3.21 LEDの寿命

[参考]　寿命推定についての論文等

(1) A.Welsh Jr., L.Fu, W.W.So and H.Yuan : "Die-Attach Epoxy Reliability of InGaN LED's", Solid State Lighting II, Proceedings of SPIE, vol. 4774 (2002), 68-73

(2) S.F.Jacob : 3rd International Conference on Solid State Lighting, "Maximizing Useful SSL Lifetime", Proceedings of SPIE, vol. 5187 (2003), 76-84

(3) N.Narendran, L.Deng, R.M.Pysar, Y.Gu and H.Yu : "Performance Characteristics of High-Power Light-Emitting Diodes", 3rd International Conference on Solid State Lighting, Proceedings of SPIE, vol. 5187 (2003), 267-275

(4) Y.Gu, N.Narendran and J.P.Freyssinier : "White LED Performance", 4th International Conference on Solid State Lighting, Proceedings of SPIE, vol. 5530 (2004), 119-124

(5) D.L.Barton, M.Oshinski, P.Perlin, P.G.Eliseev and J.Lee : "Single-quantum well InGaN green light emitting diode degradation under high electrical stress" Microelectronics Reliability 39 (1999) 1219-1227

(6) T.Yanagisawa : "Estimation of the Degradation of InGaN/AlGaN Blue Light-Emitting Diodes", Microelectron. Reliab., vol. 37 (1997), No. 8, 1239-1241

(7) A.Nakanishi and T.Moriyama : "Life-time Projection of white LED for Lighting", H16 照明学会大会予稿集 (2004), p229

(8) S.Ishizaki ,H.Kimura, M.Sugimoto : "Estimating Life Time of High Power White LED", H17 照明学会大会予稿集 (2005), p242

2.6 信頼性についての規格・試験方法

2.6.1 熱的環境試験

2.6.1.1 半田耐熱試験（半田付け時の熱に対する耐久性試験。ディップ試験とリフロー試験がある）

(1) EIAJ ED-4701/300	半導体デバイスの環境及び耐久性試験方法(強度試験 I)2001年8月	試験方法302　はんだ耐熱性試験(SMD以外)
(2) MIL-STD-750-1995	Test methods for semiconductor devices	2031.2 Soldering heat
(3) JIS C 60068-2-20 1996	環境試験方法—電気・電子—はんだ付け試験方法	
(4) EIAJ ED-4701/300	半導体デバイスの環境及び耐久性試験方法(強度試験 I)2001年8月	試験方法301　はんだ耐熱性試験(SMD)
(5) JIS C 60068-2-58 2002	環境試験方法—電気・電子— 表面実装部品(SMD)のはんだ付け性、電極の耐はんだ食われ性及びはんだ耐熱性試験方法	

2.6.1.2 温度サイクル試験（温度変化に対する耐久性試験）

(1) EIAJ ED-4701/100	半導体デバイスの環境及び耐久性試験方法(寿命試験 I)2001年8月	試験方法105　温度サイクル試験
(2) MIL-STD-883F-2004	Test methods and procedures for microelectronics	1010.8 Temperature cycling

2.6.1.3 熱衝撃試験（急激な温度変化に対する耐久性試験）

(1) EIAJ ED-4701/300	半導体デバイスの環境及び耐久性試験方法(強度試験 I)2001年8月	試験方法307　熱衝撃試験
(2) MIL-STD-883F-2004	Test methods and procedures for microelectronics	1011.9 Thermal shock

2.6.1.4 温湿度サイクル試験（温湿度変化に対する耐久性試験）

(1) EIAJ ED-4701/200	半導体デバイスの環境及び耐久性試験方法(寿命試験 II)2001年8月	試験方法203　温湿度サイクル試験
(2) MIL-STD-883F-2004	Test methods and procedures for microelectronics	1004.7 Moisture resistance
(3) JIS C 60068-2-38 1988	環境試験方法(電気・電子)温湿度組合せ(サイクル)試験方法	

2.6.2 機械的環境試験

2.6.2.1 振動試験(可変周波数)(輸送中及び使用中における振動に対する耐久性試験)

(1)EIAJ ED-4701/400	半導体デバイスの環境及び耐久性試験方法(強度試験Ⅱ)2001年8月	試験方法403　振動試験
(2)MIL-STD-883F-2004	Test methods and procedures for microelectronics	2007.3 Vibration, variable frequency
(3)JIS C 60068-2-6 1999	環境試験方法—電気・電子—正弦波振動試験方法	

2.6.2.2 衝撃試験(輸送中および使用中における衝撃に対する耐久性試験)

(1)EIAJ ED-4701/400	半導体デバイスの環境及び耐久性試験方法(強度試験Ⅱ)2001年8月	試験方法404　衝撃試験
(2)MIL-STD-883F-2004	Test methods and procedures for microelectronics	2002.4 Mechanical shock
(3)JIS C 60068-2-27 1995	環境試験方法—電気・電子—衝撃試験方法	

2.6.2.3 定加速度試験(輸送中および使用中における定加速度に対する耐久性試験)

(1)EIAJ ED-4701/400	半導体デバイスの環境及び耐久性試験方法(強度試験Ⅱ)2001年8月	試験方法405　定加速度試験
(2)MIL-STD-883F-2004	Test methods and procedures for microelectronics	2001.2 Constant acceleration
(3)JIS C 60068-2-7 1993	環境試験方法—電気・電子—加速度(定常)試験方法	

2.6.2.4 端子強度試験(端子部分が輸送中および使用中に印加される力に対する耐久性試験)

(1)EIAJ ED-4701/400	半導体デバイスの環境及び耐久性試験方法(強度試験Ⅱ)2001年8月	試験方法401　端子強度試験
(2)MIL-STD-883F-2004	Test methods and procedures for microelectronics	2004.5 Lead integrity
(3)JIS C 60068-2-21 2002	環境試験方法—電気・電子— 端子強度試験方法	

2.6.3 その他の環境試験

2.6.3.1 塩水噴霧試験(塩水雰囲気での腐食に対する耐久性試験)

(1)EIAJ ED-4701/200	半導体デバイスの環境及び耐久性試験方法(寿命試験Ⅱ)2001年8月	試験方法204　塩水噴霧試験
(2)MIL-STD-883F-2004	Test methods and procedures for microelectronics	1009.8 Salt atmosphere (corrosion)
(3)JIS C 60068-2-11 1989	環境試験方法(電気・電子)塩水噴霧試験方法	

2.6.3.2 気密性試験(デバイスの気密性を評価する)

(1)EIAJ ED-4701/500	半導体デバイスの環境及び耐久性試験方法(その他の試験)2001年8月	試験方法503　気密性試験
(2)MIL-STD-883F-2004	Test methods and procedures for microelectronics	1014.11 Seal
(3)JIS C 60068-2-17 2001	環境試験方法—電気・電子—封止(気密性)試験方法	

2.6.3.3 半田付け性試験(端子部分の半田濡れ性を評価する)

(1)EIAJ ED-4701/300	半導体デバイスの環境及び耐久性試験方法(強度試験Ⅱ)2001年8月	試験方法303　はんだ付け性試験
(2)MIL-STD-883F-2004	Test methods and procedures for microelectronics	2003.8 Solderability
(3)JIS C 60068-2-20 1996	環境試験方法—電気・電子—はんだ付け試験方法	

2.6.3.4 静電破壊試験(静電気に対する耐性を評価する)

(1)EIAJ ED-4701/300	半導体デバイスの環境及び耐久性試験方法(強度試験Ⅱ)2001年8月	試験方法304 人体モデル静電破壊試験(HBM/ESD)
(2)MIL-STD-883F-2004	Test methods and procedures for microelectronics	3015.7 Elastic discharge sensitivity classification

2.7 安全性についての規格・試験方法

2.7.1 電気的安全性

(1) JEL811 2005	照明用白色LEDモジュール安全性要求事項	6. 感電に対する保護(充電部分の露出について) 7.1 絶縁抵抗(充電部と人が触れる可能性のある可触部分の電気特性について) 7.2 耐電圧性(充電部と人が触れる可能性のある可触部分の電気特性について) 13. 保護接地(接地端子について) 14. 過電力試験(過電力値による点灯状態について) 15. 故障状態における安全性(故障状態での安全性について) 17. 沿面距離及び空間距離(絶縁距離の最低要求事項について)

2.7.2 機械的安全性

(1) JEL811 2005	照明用白色LEDモジュール安全性要求事項	8. ねじ、充電部および接続部(充電部機械的接続部分の機械的応力について) 9. 端子 [Terminal](電線を止めるための端子について) 10. 電気接続(口金、コネクタおよび端子について) 11. 耐熱性(絶縁部品および電撃保護用絶縁部品の耐熱性について) 12. 耐難燃性(絶縁部品および電撃保護用絶縁部品の耐炎性、耐着火性、耐火性について) 16. 構造(絶縁に使用してはならない材料について)

2.7.3 生体的安全性

(1) CIE S 009/E 2002	Photo biological Safety of Lamps and Lamp Systems (照明用光源と光生物的障害について)	
(2) JIS TS C 0038 2004	ランプ及びランプシステムの光生物学的安全性【(1)の翻訳】	
(3) IEC 60825-1	Safety of laser products	第1部：機器のクラス分け、要求事項及び使用者の手引(過度の光の照射によって誘起される人体(目と皮膚)への病理学的作用について)
(4) JIS C 6802 2005	レーザ製品の安全基準【(3)の翻訳】	
(5) JEL811 2005	照明用白色LEDモジュール安全性要求事項	18. 発光の安全(集光や拡散する発光に対する安全性)
(6) 21CFR Chapter 1 Subchapter J	Radiological health Part1000～1040[米国FDA]	

［付録］関連規格一覧と国内組織

CIE 規格	CIE : Commission Internationale de l'Eclairage（国際照明委員会） 問合せ先：(社) 日本照明委員会 [http://www.ciejapan.or.jp/] 〒101-0048 東京都千代田区神田司町 2-8-4 Tel：03-5294-7200
EIAJ 規格 (現JEITA 規格)	JEITA：Japan Electronics and Information Technology industries Association（電子情報技術産業協会） 問合せ先：(社) 電子情報技術産業協会 標準技術部 [http://www.jeita.or.jp/] 〒101-0062 東京都千代田区神田駿河台 3-11 Tel：03-3518-6434
IEC 規格	IEC：International Electrical Commission（国際電気標準会議） 問合せ先：(財) 日本規格協会 普及事業部 [http://www.jsa.or.jp/] 〒107-8440 東京都港区赤坂 4-1-24 Tel：03-3583-8042
ISO 規格	ISO：International Standardizing Organization（国際標準化機構） 問合せ先：(財) 日本規格協会 普及事業部 [http://www.jsa.or.jp/] 〒107-8440 東京都港区赤坂 4-1-24 Tel：03-3583-8042
JIS 規格	JIS：Japan Industrial Standard（日本工業規格） 問合せ先：(財) 日本規格協会 普及事業部 [http://www.jsa.or.jp/] 〒107-8440 東京都港区赤坂 4-1-24 Tel：03-3583-8042
JEL 規格 (JELMA により制定)	JELMA：Japan Electric Lamp Manufacturers Association（日本電球工業会） 問合せ先：(社) 日本電球工業会 技術部 [http://www.jelma.or.jp/] 〒100-0006 東京都千代田区有楽町 1-7-1 Tel：03-3201-2641
JIL 規格 (JLA により制定)	JLA：Japan Luminaires Association（日本照明器具工業会） 問合せ先：(社) 日本照明器具工業会 技術部 [http://www.jlassn.or.jp/] 〒110-0005 東京都台東区上野 3-2-1 Tel：03-3833-5747
MIL 規格	MIL：Military Specifications and Standards（アメリカ軍用規格） 問合せ先：(財) 日本規格協会 普及事業部 [http://www.jsa.or.jp/] 〒107-8440 東京都港区赤坂 4-1-24 Tel：03-3583-8042
アメリカ連邦規則	Code of Federal Regulations（アメリカ連邦規則） 問合せ先：(財) 日本規格協会 普及事業部 [http://www.jsa.or.jp/] 〒107-8440 東京都港区赤坂 4-1-24 Tel：03-3583-8042

(注) 各規格ともDraft版については原則公開されていない

第3章

設計ガイドライン編

本章では、白色LEDを用いた応用製品の設計に関する事項を解説する。応用製品にも多くの種類があるが、白色LEDを使って照明器具を構成することを中心課題とする。照明器具は、光を発生する「光源部」、光源に電力を供給する「電源回路部」、光源からの光を利用形態に合わせて適切な方向に制御する「配光制御部」、各部を保持して包み込む「筐体部」などから構成される。

光源部については、第1章で詳細解説されているので、まず「配光制御」を行うための技術＝「光学設計」について解説し、次にLEDに電力を供給するための技術＝「回路設計」について解説する。LEDは、「長寿命」というすぐれた特長があるが、その特長を現実のものとする技術＝「信頼性設計」について、最後に、安心して使うためのさまざまな留意事項を「安全性設計」としてまとめた。

LED照明実現の指標として、従来光源と比較して、LEDの発光効率（lm/W）の上昇が注目されているが、この値は光源部の効率を表すものであり、実際に人の生活する部屋を照明する場合は、電源回路を通して電力が供給され、照明器具の光学系を介して光を利用することになる。したがって、電源回路の変換効率と照明器具の光学的な効率に光源の効率を掛け合わせた値が、照明システムとしての効率になる。光学系や回路部もLED素子自体と同様に大きな役割を果たしていることを本章から読み取って頂きたい。

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