國立交通大學
National Chiao Tung University

出國報告（出國類別：學研訪問）

拜訪東京工業大學及神奈川大學 Fukushima 教授及 Iwakura 准教授研究團隊

服務機關：國立交通大學 應用化學系
姓名職稱：增原宏 講座教授
派赴國家：日本東京工業大學/橫濱神奈川大學
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摘要

I visited Prof. Takanori Fukushima at Tokyo Institute of Technology, exchanged our opinions on relevant topics, and discussed on our collaboration. Our results are summarized and its title is “Fluorescence microspectroscopic study on aggregation-induced emission enhancement of a tetraphenylethene derivative by laser trapping”.

Also I visited Prof. Izumi Iwakura at Kanagawa University and asked her opinions about one of our recent topics “Femtosecond lase induced crystallization of molecules in solution”. She is currently started a new subject on “Femtosecond laser induced crystallization of sugars” which is similar to our topic. We could have nice discussion and extended comparable consideration, and consequently we came to a tentative conclusion that more systematic examination of sugar crystallization is necessary.

我拜訪了東京工業大學的 Takanori Fukushima 教授，交換我們彼此對於近期實驗的意見，並且討論我們未來合作的機會。我們近期研究的結果為：螢光顯微光譜探討雷射捕陷四苯乙烯衍生物之聚集誘導發光增強。

我也訪問了神奈川大學的 Izumi Iwakura 教授也討論了有關於我們近期的主題:飛秒雷在水溶液中誘導結晶。他最近也開始了與我們相關的新主題：飛秒雷射誘導糖結晶。我們有一個非常棒的討論內容，並且拓展彼此的意見，得到一個對於糖結晶實驗較有系統的結論。

目次

本文

一、目的

In the past 9 years we have systematically extended experimental studies on laser trapping dynamics and chemistry of molecules and nanoparticles. As trapping light sources 1064 nm CW and 800 nm femtosecond lasers are used, while target objects are molecules, supramolecules, polymers, polymers spheres, gold nanoparticle. Our research covers wide range of chemistry and needs various techniques of laser, optics, and spectroscopy. Therefore intimate collaborations are indispensable and this time I visited Prof. Fukushima to discuss on laser trapping assembling of his molecules, while I visited Prof. Iwakura for discussing various subjects on development and application of femtosecond laser.

在過去的九年，我們成功的現拓展分子與奈米粒子的雷射捕陷動力學與化學的實驗。我們的實驗目標物是分子、超分子、聚合物與金奈米粒子等等；而雷射利用 1064 nm 連續式雷射與 800 nm 飛秒雷射。我們的研究涵蓋非常廣的化學領域且需要許多不同的技術如；雷射、光學元件以及顯微鏡。因此這些合作對我們而言是密不可分的，所以這次我在訪問 Fukushima 教授討論利用他的分子進行雷射捕陷聚合的同時，也訪問了 Iwakura 教授一起討論飛秒雷射的發展與應用。

二、過程

（一）3/14-3/15　Visiting Prof. Takanori Fukushima at Tokyo Institute of Technology

1. I reported our recent activity and research progress of Laser Bio/Nano Science Laboratory in DAC NCTU.
2. Prof. Fukushima introduced his laboratory activity at Tokyo Institute of Technology. It is indeed a typical advanced case of synthetic chemistry laboratory and its management seemed very well organized like business office of big companies. We discussed generally roles of light, supramolecule,

optical and photo-functionality in molecular science.

3. The discussion on our collaboration of “Fluorescence microspectroscopic study on aggregation-induced emission enhancement of a tetraphenylethene derivative by laser trapping” is summarized here.

   Until now Laser Bio/Nano Science Laboratory has demonstrated various laser trapping-induced phenomena such as assembling and crystallization for molecules and nanoparticles, and elucidated their trapping dynamics and mechanism. For developing systematically these results, we have been studying on laser trapping-induced aggregation of a tetraphenylethene derivative, and consider its formation mechanism based on the temporal change in fluorescence properties during the aggregation. The findings in this work will contribute to the elucidation of the mechanism of aggregation-induced emission enhancement.

   A continuous-wave laser beam of 1064 nm was focused at an air/solution interface of phosphate D2O buffer solution of a tertiary ammonium-appended tetraphenylethene through an objective lens. A 405 nm-laser was used as an excitation light source to collect the fluorescence image and spectrum of the aggregate formed by laser trapping. Figure 1 shows the transmission (i-iii) and fluorescence (iv) images of aggregates induced by laser trapping. At 109 sec after starting irradiation, a few μm-sized single aggregate was generated at the laser focus, when the fluorescence was hardly observed. The continuous irradiation led to the further aggregate growth, and the aggregates eventually grew to be about 10 μm, when the strong fluorescence was observed (iv). Separately, we measured the temporal change of the fluorescence spectrum at the center of aggregate during laser trapping (Figure 1b). With the aggregate growth, the fluorescence intensity was drastically enhanced and simultaneously the band was red-shifted, depending on the laser power. We

analyze the present change of the fluorescence spectrum depending on the position of the resultant aggregate, by which the dynamics and mechanism of the aggregation is being clarified.

（一）3/14-3/15 拜訪東京工業大學的 Takanori Fukushima 教授

1.我報告了交通大學應用化學系雷射生物奈米科學研究室近期的活動以及研究。

2.Takanori Fukushima 教授介紹他在東京工業大學的實驗室研究，這的確是一間非常先進的典型有機合成實驗室。他們的實驗室管理也是非常好的猶如大型公司裡的辦公室。我們討論了光、超分子、光學元件與光子的功能在分子科學上扮演的腳色。

3.關於「螢光顯微光譜探討雷射捕陷四苯乙烯衍生物之聚集誘導發光增強」的合作討論，總結如下。

迄今雷射生物奈米科學研究室已演示出多種雷射捕陷誘導之現象，如：分子的結晶化及奈米粒子的聚集化，並且進一步地闡述其捕陷動態與機制。為了條理化地發展以上成果，我們藉由雷射捕陷來誘導四苯乙烯衍生物產生聚集作用，並根據其聚集化過程中螢光性質的變化來思考其生成機制。而此研究的發現必將有助於闡明聚集誘導發光增強之生成機制。

1064 奈米的連續波雷射通過物鏡聚焦於四苯乙烯衍生物溶液的液氣介面，再導入另一 405 奈米雷射作為激發光源，使雷射捕陷所生成的聚集體放出螢光，並偵測其聚集化過程的螢光影像及螢光光譜。圖一〈a〉為雷射捕陷生成的聚集體透射影像〈i-iii〉及螢光影像〈iv〉：在近紅外光雷射聚焦於液氣介面 109 秒後，於其焦點處生成一數微米大小的聚集體，然而，此聚集體的螢光卻微弱至難以發現。但在持續地照射下，聚集體進一步地成長，並於此時放出強烈的螢光〈iv〉，而其直徑大小最終可達至約 10 微米。另一方面，我們在雷射捕陷過程中，量測聚集體中心隨時間變化之螢光圖譜〈圖一 b〉：隨著聚集體的成長，其螢光強度顯著地提升，並同時伴隨著螢光波峰的紅位移。之後，我們針對所得的聚集體量測其不同位置的螢光圖譜，並藉由分析圖譜的變化來闡明雷射捕陷誘導聚集作用之動態與作用機制。

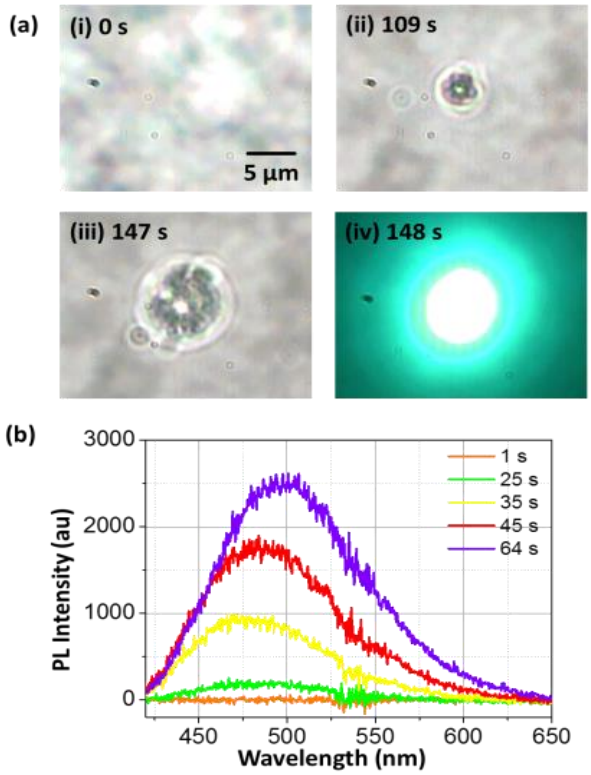

Figure 1: (a) Transmission and fluorescence images of the aggregate and (b) time evolution of fluorescence spectra of aggregate during laser trapping.

圖一：(a) 聚集體的透射影像及螢光影像 (b) 於雷射捕陷過程中，聚集體隨時間變化之螢光圖譜

（二）3/16-3/18 Visiting Prof. Izumi Iwakura at kanagawa University

1. I reported our recent activity and research progress of Laser Bio/Nano Science Laboratory in DAC NCTU.
2. Prof. Iwakura introduced her laboratory activity at Kanagawa University. I was so impressed to see that a young lady chemistry professor has successfully set excellent ultrafast laser spectroscopy systems in nice clean room and is applying them to explore new phenomena and analyze their dynamics. The total cost of the facility would be about 70 million NTD.
3. We had nice discussion on “Femtosecond laser induced crystallization of molecules in solution”. She is currently started a new subject on femtosecond laser induced crystallization of sugar which is similar to our topic. She has

found that the sugar is deposited on a sample bottle wall above the sugar solution when coherent Raman processes is induced with intense femtosecond white band illumination. Considering melting/vaporization of sugar, conventional evaporation followed by deposition in air should be difficult. Thus I proposed that intense coherent vibrational excitation of solvent methanol results in solution ablation and ejected small droplets reaching the wall. Then methanol is vaporized leaving small crystals of sugar. In order to confirm this idea, the following experiments are planned; 1) several sugars are examined, 2) laser threshold is determined in different solvents, 3) correlations between crystallization behavior and various laser parameters, 4) correlations between crystallization behavior and chemical structure of sugars, and 5) correlations between crystallization behavior and physical parameters of various solvents.

（二）3/16-3/18 拜訪神奈川大學的 Izumi Iwakura 教授

1.我報告了在交通大學應用化學系雷射生物奈米實驗室最近的實驗進度。

2.Iwakura 教授介紹了他在神奈川大學的實驗室。我印象很深刻，這樣一位年輕的女化學教授能這樣成功的應用超快雷射在實驗上，研究且分析他的動力學現象。整套系統需花費 7 仟萬臺幣架設。

3.我們討論關於飛秒雷射誘導結晶化的現象結論非常正面。他現在正開始一個新的計劃於飛秒雷射誘導糖類的的結晶，這是非常類似於我們實驗室的研究內容。他發現糖會沉積在樣品瓶壁上，當飛秒雷射白光寬帶照射時會誘發同調拉曼。考慮到糖的融解/蒸發，傳統的蒸發會跟隨著沉積，應該會相當困難。因此我建議甲醇溶劑的高強度同調震動態激發導致溶液中的消融或是噴射小的液滴在瓶壁上。然後甲醇會被蒸發僅留下小的糖結晶。為了證實這個想法，計畫接下來的實驗，(1)一些糖被檢驗，(2)確立雷射門檻再不同溶液中，(3)結晶現象與各種雷射參數的關係，(4)結晶現象與糖化學結構的關係，(5)結晶現象與各種溶劑物理性質的關係。

三、心得及建議

（一）心得

During this business trip, I had very fruitful discussion in Tokyo Institute of Technology and Kanagawa University. Prof. Fukushima gave me stimulating viewpoints from his long experience as organic chemist, and we promised to develop our collaboration toward publication of our collaborative work. Prof. Iwakura proposed further analysis on femtosecond laser crystallization of sugar in her laboratory.

此趟出差，在東京工業大學和神奈川大學我與教授們的討論使我收穫良多。Fukushima 教授是一位豐富經驗的有機化學家，激發我許多觀點，我們將會發展雙方實驗室間的合作關係。Iwakura 教授提議在他的實驗室對飛秒雷射糖的結晶化更進一步的分析。

(二）建議

With Prof. Fukushima we will be able to publish a paper in this year. Prof. Iwakura has already started new experiments based on our discussion, and she has set a plan visiting NCTU with new data at the end of this March. She, her student Mr. Sena Hashimoto, and her advisors, Prof. Keitaro Yoshiyara (IMS Okazaki in Japan) and Prof. Keiko Sasaki (Tokai University in Japan) are coming to Laser Bio/Nano Science Laboratory. Our collaborations are being developed tightly.

由於 Fukushima 教授的幫忙，我們能夠在今年發表一篇論文。討論後，Iwakura 教授已經開始新的實驗，也計畫參訪交通大學。他及他的學生 Sena Hashimoto、他的指導教授 Keitaro Yoshiyara（日本岡崎分子科學研究所），Keiko Sasaki 教授（東海大學）會拜訪我們雷射生物奈米科學實驗室。我們實驗室間合作是相當緊密的。

四、附錄

Photos of entrance of clean room（無塵室入口）

detection system above clean room（偵測系統）

femtosecond laser spectroscopy systems（飛秒雷射顯微系統）