澳洲用戶 Dr. Petravic

追逐軟X光—永不停息的腳蹤

世界上充滿千百種人，話說科學家亦各具特色。有些研究人員終其一生追逐龍捲風的蹤跡、或有考古學家投注畢生精力尋找失落的帝王陵墓，然而長居於澳洲Canberra城市的Mladen的最愛是找尋高穩定度的軟X光。我們若追溯這位NSRRC用戶過去10年周遊世界各國的足跡，好比相當於建構出一幅同步輻射軟X光演進的過程。

Dr. Mladen Petravic, at the Soft X-ray experimental station, NSRRC, Taiwan

近幾年來，許多光源中心的發展趨勢一致朝著投資硬X光的設施興建方向前進，主要為便利生物化學研究的需求，同時積極朝微觀世界尋求更深入的了解。然而運用於探討半導體材料表面之光子激發與吸收特性的實驗工具裏，屬於較低能譜的軟X光仍獨具其不可取代的地位，基於這原因，這位喜愛中國美食的澳洲國立大學電子材料工程系研究學者與NSRRC結了不解之緣。

面對一位長年周遊於各國家實驗室使用軟X光光源進行表面物理實驗的異地學者，不禁令人好奇的想聽聽Mladen Petravic博士的經驗和感想。「當您必須選擇一個實驗室進行研究的時候，您是依據那些因素來決定?」Mladen毫不猶豫的回答：「地利為先。」其次是實驗儀器的解析度、光源的穩定性等等。面對著不斷收集偵測數據的電腦銀幕、很難聯想眼前這位毫無倦容的大個子已連續工作了19小時，他侃侃而談的表示「建造一座光源中心工程耗大而且十分昂貴，若再加上周邊跨領域實驗設施更不易。基於此，全世界光源中心若能更密切的溝通合作、截長補短、互補不足，興建不同的實驗站並彼此交換使用，如此一來，以同步輻射為基礎的研發項目將十分可觀。」言語之中自然流露出我們所熟悉「科學無國界」研究者的情懷。

坐在本中心超寬光譜光束線（BL 24, Wide Range Beamline）光電子發射與光吸收實驗站旁，Mladen述說與同步輻射光源的初逢經驗。1996年他首次在法國LURE光源中心使用同步輻射進行電子激發實驗。由於同步輻射光源強度高、可調度大、能量強、並且實驗場所24小時運作不斷，正是任何科學家夢寐以求的研究環境。自那一刻起，這位物理學者對同步輻射實驗環境便情有獨鍾。如此一路走過將近10年的歲月，軟X光成了他不可或缺的實驗工具。然而，誠如每位致力研究的人再熟悉不過的情況：探討艱深的原子領域，除了方向正確、選擇合適的樣品之外，常常決定於是否能找到充分配合實驗理論需求的儀器，更甚於此，儀器的精準決定成果的好壞。為了進行某些先進的半導體材料研發，Mladen尋覓各方，發現目前世界只有兩處光源中心裝置了他需要的特殊實驗站。其中一座實驗站位於法國、剩下的另一座則屬於台灣的NSRRC。回到「地利為先」的考量，Mladen便成了NSRRC用戶。

他有如身經百戰的老兵見識過各種不同的實驗環境與文化，體會不同格調，覺得十分有趣。譬如待在韓國的Pohang光源中心的一段日子，見識當地國民積極參與推動基礎科學研究的熱誠令人感受深刻。而NSRRC與其他光源中心最不一樣的特色，則是擁有工作認真、知識與經驗相當豐富的研究人員及儀器支援團隊，無私的不斷協助用戶克服困難，這種上好的實驗環境實在難求。更可貴的是NSRRC設計裝配的儀器其精準度超過一般國際水平之上。Mladen誠懇表示，「相信台灣人民一定引以為榮。」

Chasing the Soft X-ray

Some scientists chase tornados. Others look for archaeological tumulus. For Mladen, a resident of Canberra (Australia), it's Soft X-ray he is after. If we plot his footsteps where Mladen has been for his research during last decade, it will be like a chart of Soft X-ray advancement with year, location, and photon energy as X, Y, Z axis.

While many synchrotron facilities focus on increasing needs of Hard X-ray, there are studies, particularly in the area of materials characterization, where soft X-ray is the best instrumental media to explore photo stimulated emission and desorption on surfaces of semi-conductors. For this reason, many physicists are

following the development of soft X-ray experimental stations.

That prompted us to get the first hand information from Dr. Mladen Petravic, a fellow researcher of Department of Electronic Materials Engineering, Australian National University, who traveled intensively in the past decade between continents looking for available beam times, well-equipped experimental stations (a.k.a. End Station), high quality calibrated instruments, and professional collaborative assistance to conduct his experiments, and sometimes, experiments with his students.

What determines the final choice of a synchrotron which users settle for their tasks? "Geographical convenience of course comes first." Mladen smiles without a trace of tiredness during his interview in September 2004 at NSRRC near 24A Station, a Wide Range Spherical Grating Monochromator beamline, specially setup for a range of high resolution spectroscopies, where he spent over a week, working nearly 16-19 hours a day.

"I am yet to see better networking among synchrotron facility worldwide that allows synchrotron users to shorten the lengthy search process of available end stations and equipment. For example, an centralized information-sharing website will do."

It was not long before Mladen fell in love with synchrotron facility in 1996, while working in LURE France, a second-generation light source. Impressed by its large scale, tunable photon energy, 24-hour availability, to name few attractive advantages from scientific viewpoint, he started using Soft X-ray for characterization and modification of semiconductor surfaces. Today, much of his experiments relies on similar setting in which a combination of Soft X-ray and a suitable chamber is a must.

This is a problem! In the case of photon stimulated desorption, Mladen only located two end stations which satisfied his configuration requirements. One in France and the other in NSRRC Taiwan. "The fact is, there are many ion beamlines and chambers, but no suitable end stations. That's the challenge to users when looking for places in order to conduct their tasks," he explains.

To overcome costly operation and fast growing new technique for conducting advanced scientific research, synchrotron centers are seeking collaboration by entering join programs, or sponsoring beamlines in each other's facilities. This is a trend in light source development and an encouraging move toward information sharing that goes beyond geographical or political boundaries.

"When all requirements for proceeding the experiments are in place, it is always a bonus when the environment is friendly and assistance is available. By that standard, NSRRC is a friendly and helpful place. I enjoy working with people here, not to mention that I like Chinese food to begin with," says Mladen. Dedicated staff with trained technique mastering the instruments and loading the samples can save significant effort during the process. For a full week trip to Taiwan, time is gold. Any minute spent on getting warm up with the experimental technique, which might apply only once a year, is considered a luxury. Working with skilled staff at Station 24A established his confidence in NSRRC while the facility determined his choice of laboratories. That is, if the tropical humidity doesn't beat this strong willed scientist.

Is there any unforgettable moment while visited NSRRC? "Riding bicycle downhill toward downtown. It's fast and a pleasant trip to buy local fruits." But, don't ask him how he got back to the hill during hot summer time. "And, the most expensive Pizza Hut I ever had."

When asked about the impression of each synchrotron facility he has been, "Every facility has its uniqueness and all places I have been are world class labs including NSRRC, with superior capability as that of Japan and US. Your local people should be proud of this institute, only if they are aware of it." Synchrotron at Pohang Korea is a category of its own, persistently promoting its synchrotron publicity among its country fellows, closely working with the media and putting effort on educating school kids and graduates. They are aiming for the future and long-term commitment from their next generation.

Although culture plays a key role in communications and promotions, funding channels are the actual factors on which an institute sets its tone. That explains the aggressive marketing strategy such as Australian Synchrotron and Canadian Light Source. Because much of the funding is provided by government, but not hundred percent, Australian Synchrotron needs to seek for financial support for each beamline and end station from private segments and universities. Naturally, the effort to help the public understand what synchrotron light source is, what it does and what benefit it can bring to the society becomes essential and critical in the process.

Are there trends that the synchrotron facilities fully funded by government will adopt the idea of being privatized in the near future? That's everyone's guess. One rule never changes: investment needs to be justified by its outcomes in order to survive in the current economic situation.

To continue advanced research in basic science requires talent, technique, theory, good experimental ideas, and access to superior world class

synchrotron facility. It can be extremely time consuming and costly if scientists don't have access to synchrotron in their local environment, as a result of traveling and delay of being able to conduct recurring experiments.

That is the case in Australia, at least for now, before completion of Australian Synchrotron in 2007. With only one beamline dedicated to Soft X-ray in its current design, an estimated capacity of 40 experiments a year, Mladen still sees himself as "a man chasing Soft X-ray", if not forever, at least for a while.

Epilogue 後記

Most people experience their closest encounter with an X-ray machine at a doctor's office. Yet, the indirect influences of X-rays on our daily lives have been steadily growing. And the trend is accelerating. Today, X-rays are a key research tool in a multitude of scientific area, far more than Wilhelm Roentgen could have imagined when he accidentally discovered them in 1895.

One of the key research areas for X-ray technology today is the use of Soft X-rays, consisting of relatively high energy photons. Soft X-rays are a portion of the electromagnetic spectrum with a wavelength of approximately 10 nanometers (10E-9). Hard X-rays, whose wavelength is even shorter, have been widely applied in biology, but the fact that the gentler Soft X-rays interact with materials in many different ways makes them useful in a wide range of new applications. Soft X-ray research requires sophisticated equipment such as the National Synchrotron Radiation Research Center (NSRRC) Taiwan, one of about 70 centers in the world capable of advanced research in the area.

Chasing X-rays, not rainbows

"I am always chasing rainbows" sang Judy Garland, but some modern scientists seem to be chasing Soft X-rays instead. Take Dr. Mladen Petravic of the Department of Electronic Materials Engineering, Australian National University in Canberra, Australia. If we plot his footsteps for the last decade, we practically get a map of Soft X-ray development across the world. And for good reason: the use of Soft X-rays is a powerful technique for the characterization and modification of semiconductor surfaces.

Applications in many shapes and colors

The rising demand for high energy Soft X-rays is based on their usefulness in many application areas. For instance, high resolution dry etching of semiconductor materials is now an important technology for sophisticated microelectronic devices. During the etching process, the use of plasma etching and the bombardment of the semiconductor surface with charged particles may cause significant damage. The problem may be avoided by the use of specific molecules charged by Soft X-rays and absorbed by the semiconductor surface. The combination of these creates a damage-free, photon-excited etching process.

Microelectronics is another example. Here, the use of high-brilliance Soft X-rays will be able to check the quality of silicon items and improve the production process with less involvement from toxic chemicals. By helping the technology of microelectronics, Soft X-rays will impact our day-to-day activities through all kinds of appliances.

The joining of global research forces

Some synchrotron centers across the world are now joining forces to ease their operational costs and to share the fast growing techniques for advanced research. They are starting joint development programs, and sponsoring equipment in each other's facilities. This information sharing trend in light source development goes beyond geographic and political boundaries.

The website WWW.LIGHTSOURCES.ORG is available in early 2005. It is managed by consensus and is sponsored by the European Synchrotron Radiation Facility (France), the Argonne National Laboratory (USA), NSRRC (Taiwan) and 12 more light source centers. All accelerator-based facilities have been invited to become members of the group.

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