平成 29年 5月 9日

国立研究開発法人理化学研究所
理事　松本洋一郎

# 平成 28 年度実施 主任研究員の研究業績レビュー（中間）の結果について

主任研究員、准主任研究員及び上席研究員研究業績評価実施細則（平成 28 年 4 月 28 日細則第 46 号）に基づき主任研究員の研究レビュー（中間）を実施し、評価結果は以下のとおりです。

## １．評価対象：東原子分子物理研究室　　東 俊行 主任研究員

### １）評価体制

実施日：平成 29 年 1 月 31 日（火曜日）
4 名の所外有識者を評価委員とするヒアリングレビューを実施。
評価者：
Kenji KIMURA, Professor
Kyoto University

Satoshi YAMAMOTO, Professor
The University of Tokyo

Kaoru YAMANOUCHI, Professor
The University of Tokyo

Andreas WOLF, Professor
Max Planck Institute for Nuclear Physics, Germany

### ２）評価結果の概要等

*General comments:*

【Reviewer 1】

**i) Research Objectives:** Dr. Azuma is studying atomic, molecular, and optical (AMO) physics in a wide energy range from meV to GeV. His broad scope of interest in such a wide energy range allows him to study fundamental and important problems in atomic and molecular physics, which constitute originality and novelty of his works.

**ii) Research Results:** Since his association with RIKEN as a chief scientist 8 years ago, he and his group has made remarkable achievements in this field. The most important achievement is the development of the cryogenic electrostatic ion ring storage (RICE). This new and original apparatus allow us to study various chemical reactions and physical phenomena in very cold conditions, and will have strong impact on both physics and chemistry. They have already succeeded in test operations, and many new results will be coming out for the next few years. In addition to the developmental work, Dr. Azuma and his group have been conducting scientific studies using other facilities. Representative highlights are (1) discovery of the inverse internal conversion (IIC) in the linear carbon cluster anion $C_6^-$, (2) resonant photodetatchment of the positronium anion to test precise quantum mechanics

calculations of this simple three-body system, and (3) resonant coherent excitation of fast highly-charged ions to examine quantum electrodynamics. These studies are all original, and have high impact on the AMO physics.

**iii) Management of the Laboratory:** Dr. Azuma is managing his group very well. Smooth and quick completion of the RICE apparatus totally owes to his excellent management. Developmental works and scientific studies are being carried out in good balance. In addition, Dr. Azuma is steadily growing younger generations. It is very nice to hear that Dr. Nakano, who made substantial contributions to RICE, will have a new good position outside RIKEN.

**iv) Future research plans:** Dr. Azuma has interesting plans to extend his works with RICE and other facilities. In particular, RICE has high potential in cold molecular ion beam experiments, and various collaborations with physicists, chemists, and astronomers are highly expected.

**v) Overall assessment:** Above all, scientific achievements, group managements and future planning are all excellent. I am happy to conclude that the first 8 years of Dr. Azuma in RIKEN were very successful and productive.

【Reviewer 2】

Research in atomic, molecular and optical physics is essential for building up basic knowledge that also serves many areas of science and technology, from fundamental and cosmological physics to the chemical world and solid-state processes. In this laboratory, unique experimental methods are developed and applied to reveal elementary quantum phenomena which could not be addressed previously. The results have attracted strong international attention. As a worldwide unique demonstration, passage of fast highly charged ions through a crystalline solid was shown to achieve quasi-monochromatic coherent excitation in the soft-x-ray regime. The extremely strong electromagnetic field seen by a fast-moving ion in the periodic Coulomb potential of the crystal opens intriguing possibilities for fundamental spectroscopy. The laboratory also has exceptional experience in laser experiments using charged particle beams. This was proven by the first detection of resonant photodetachment on the elusive positronium negative ion. Moreover, successful studies were reported on energy relaxation by recurrent fluorescence photons in small negative carbon clusters. They reveal a long-predicted phenomenon in physical chemistry on systems whose formation in space is under intense debate. As a highly attractive and timely development, the lab has built and started up a cryogenic storage ring (RICE) for fast ion beams. For the upcoming research at this instrument, the lab follows world-wide highly competitive goals, such as the implementation of charged liquid-helium droplets unprecedented at a machine of this type, as well as new merged-beams and particle-detection techniques. Substantial external funding from Japanese sources has been attracted and partly covers intended future developments. An adequate level of independence and attractive career perspectives are given to the research scientists of the lab (about three in temporal average). Number and intensity of scientific collaborations in Japan and overseas are remarkable. The Chief Scientist has an exceptionally strong international standing. It is documented by his leading positions in international physics bodies as well as his lead in the organization of large international conferences.

The lab is a highlight of RIKEN and has carried out fundamental research of excellent quality and remarkable originality. Its wide interdisciplinary connections and international integration are extremely promising for the future. The achievements are particularly impressive considering the still quite low average number of scientific members of the laboratory in the period under review. Especially the newly created cryogenic devices of the lab, in connection with the ion sources for complex molecules and laser sources, offer a unique prospect to realize interdisciplinary work towards a better understanding of molecular mechanisms for the benefit of chemistry and other applications.

【Reviewer 3】

Dr. Toshiyuki Azuma, a chief scientist of the laboratory, has been recognized internationally as one of the leading scientists in the field of AMO science. Among his recent studies, the ion storage ring spectroscopy of highly charged ions performed using an ion storage ring in Tokyo Metropolitan University is noteworthy. By detecting visible photons emitted from the electronically excited $C_6^-$, he confirmed the existence of its extremely slow radiative decay process. The idea of observing such weak fluorescence from electronically excited states, which couple strongly with the vibrationally highly excited manifold of its electronic ground state through the internal conversion, was raised first in the field of photochemistry about 40 years ago. However, since then, no conclusive studies had been performed before Dr. Azuma's recent report. Whether the extremely slow and weak fluorescence is to be called "recurrent fluorescence occurring after inverse internal conversion" is to be discussed more, but his achievement is significantly important because it shows that such photochemical processes can be detected and studied using an ion storage ring combined with highly sensitive detection systems.

Dr. Azuma is also a pioneer of experimental studies on the Okorokov effect. In optical science, atoms and molecules are excited by light, which is regarded as an oscillating electric field. Interestingly, if atoms and molecules are accelerated and injected into a solid crystal, they can be excited "optically" by the oscillating crystal field they feel when they pass through the solid crystal. This effect known as the Okorokov effect has been an attractive research topic since its theoretical prediction made more than half a century ago. By using the multiply charged atomic ion beam provided by the Heavy Ion Medical Accelerator in Chiba, Dr. Azuma demonstrated that the state selective production of doubly excited state of $Ar^{16+}$ is achieved through the Okorokov effect by double resonance scheme in the three dimensional configuration.

As can be seen in these two directions in his experimental projects I raised above, Dr. Azuma has been developing ion beam techniques as well as highly sensitive ion and photon detection techniques and has been conducting experimental studies with high originalities, which could not have been achieved only by using light. Through the interim review process, I was impressed by these pioneering scientific achievements. I am convinced that Dr. Azuma and his group, which has been managed well by Dr. Azuma, will further explore frontiers in AMO science by the cryogenic electrostatic ion storage ring newly built and installed recently in his group.

【Reviewer 4】

Azuma's lab is one of the most active groups in the field of atomic, molecular and optical physics in the world. The chief scientist Toshiyuki Azuma is currently a chair of C-15 commission (Atomic, Molecular and Optical Physics) of IUPAP. This indicates that he is one of the most respected person in this community.

The main topics of his research are atomic/molecular physics using an electrostatic ion storage ring, application of resonant coherent excitation (RCE) to atomic physics, and physics of exotic atoms/molecules. He achieved great success during the last seven years and the achievements were published in the top journals in Physics and Chemistry, such as Physical Review Letters. One of the highlights of his research is the detection of so-called *Poincaré Fluorescence* using the electrostatic storage ring. This is important to understand the evolution of interstellar molecules. Another highlight is the observation of extremely sharp resonance using RCE. This opens the way for a precise QED-check for high Z ions. He also developed a new electrostatic storage ring, RICE, in RIKEN. The design concept of RICE is very ambitious. The development was just finished and I believe interesting research results will appear soon.

He conducted these researches with junior lab members through domestic and international collaborations. He gave a clear vision to the junior members and they made significant contributions to the research. As a result, many of the former members got tenure positions in universities and research institutes. This indicates that his management of lab is also excellent.

In summary, his research accomplishment is excellent and he manages his lab quite adequately. There is no doubt that he will continue to be a leading scientist and produce excellent outcomes.

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