2012B 期 採択長期利用課題の事後評価について

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2012B 期に採択された長期利用課題について、2015A 期に3年間の実施期間が終了したことを受け、第55回 SPring-8 利用研究課題審査委員会長期利用分科会（平成27年12月21日開催）において、事後評価が行われました。

事後評価は、長期利用分科会が実験責任者に対しヒアリングを行った後、評価を行うという形式で実施し、SPring-8 利用研究課題審査委員会で評価結果を取りまとめました。以下に対象となる長期利用課題3課題の評価結果を示します。研究内容については本誌91ページの「最近の研究から」に実験責任者による紹介記事を掲載しています。

－ 課題1 －

課題名	Development of spin-resolved Compton scattering in high magnetic fields: probing the orbitals in complex oxides
実験責任者(所属)	Jonathan Duffy (University of Warwick)
採択時課題番号	2012B0045
ビームライン	BL08W
利用期間 / 配分総シフト	2012B～2015A/108シフト

［評価結果］

The purpose of this long-term project is to install a cryomagnet into the magnetic Compton scattering spectrometer at the BL08W beamline and develop studies of magnetic systems and interactions under high magnetic fields of up to 9 T and temperatures down to 1.5 K. For the duration of the project, the project group has successfully installed and tested the new system and then demonstrated that it can collect high quality data at low temperatures and high magnetic fields never achieved before at BL08W, by overcoming some technical issues, such as sample movement by magnetic field and background corrections for small samples. In addition, they have developed a software that is able to derive theoretical magnetic Compton profiles from the wave function output by the ELK code. By both the development of the experimental technique and the advance in the theoretical modeling and interpretation, they have made a methodology ready for exploitation of new measurements. This achievement is highly evaluated by the review committee.

Along with the effort on methodology, the project group has studied several materials that are scientifically interesting and technologically important. They include the electronic structure of CeB_6 with induced, anisotropic B-2p magnetization, that of $Ca_3Co_2O_6$ with Co^{3+} configuration and no oxygen spin-polarization, spin polarization in half-metal Co_2MnSi, preliminary measurement of $Nd_2Ir_2O_7$ and others. Among them, the three sets of results, i.e. CeB_6, $Ca_3Co_2O_6$ and Co_2MnSi, have been already published in a PhD thesis and presented in invited talks at a number of international conferences and meetings. However, the review committee notices that publications in scientific journals are rather delayed, although the measurements have been carried out in the second half of the project period. The committee expect that the results reported to the committee will be published in scientific journals shortly.

In summary, the review committee judges that this project has achieved its goals and evaluates it as one of successful long-term projects.

［成果リスト］

登録なし

― 課題2 ―

課題名	X 線分光法による臨界価数ゆらぎによる新しい量子臨界現象の実験的検証
実験責任者(所属)	渡辺 真仁 (九州工業大学)
採択時課題番号	2012B0046
ビームライン	BL39XU
利用期間 / 配分総シフト	2012B～2015A/183シフト

［評価結果］

本長期利用課題は、X 線分光法を用いて臨界価数ゆらぎによる新しい量子臨界現象の実験的検証を目指したものである。重い電子系金属 $YbNi_3Ga_9$ における Yb の 1 次の価数転移と臨界終点の発見により、この目的はほぼ達成されていると判断できる。本課題研究では、X 線吸収分光（XAS）測定により、幅広い温度・圧力相図の中で Yb の価数が決定された。その結果、価数クロスオーバー線が、低温極限で常磁性・反強磁性境界圧力 Pc～9 GPa 付近に収斂するという興味深い実験事実が見出された。さらに、磁場を加えた温度・圧力・磁場相図の中で、臨界終点近傍での異常な臨界現象が発見された。これらの結果は、この価数揺動系における新しい量子臨界現象を示唆するもので、臨界価数揺らぎの理論的予想と一致しており、大変興味深いものである。もう一つの大きな成果は、準結晶 $Y_{15}Au_{51}Al_{34}$ における磁場誘起の価数クロスオーバー領域の発見である。準結晶では量子臨界「点」がある拡がりを持つ量子臨界「領域」を形成するという実験結果は、強相関電子系分野だけでなく準結晶分野にも強いインパクトを与えることが予想される。このように本課題において達成された成果は、非常に学術的価値の高いものである。

一方、BL39XU のビームライン要素技術の高度化、特に、高圧下での XAS 測定のためのナノ多結晶ダイヤモンドアンビルセル（DAC）の開発により、透過 X 線強度を 1 桁高くすることに成功したことも高く評価できる。この技術開発により、比較的低エネルギー領域に吸収端を持つ化合物（Ce 化合物など）の高圧・低温下での XAS 測定が可能になったことも、本課題の大きな成果である。

本課題申請代表者は理論家であるが、ビームライン担当者をはじめとする実験家との緊密な連携によりユニークな研究グループを形成し、上記の成果を創りだしたことは注目に値する。課題採択時には、幾つかの検討事項（長期利用課題申請の根拠と道程、極低温・強磁場下での高精度圧力測定システム、および Ce 化合物用 DAC に関する事項など）が指摘されたが、そのすべてを解決して成果に結びつけている。これらの研究成果は影響力の高い論文に掲載されており、また国際会議をはじめとする多くの学会で情報発信も十分に行われている。この研究グループによる今後の研究展開（新しい研究領域開拓や実験手法開発）を期待したい。

［成果リスト］

（査読有論文）

［1］SPring-8 publication ID = 25179
H. Nakai *et al*.: “Temperature and Magnetic Field Dependent Yb Valence in $YbRh_2Si_2$ Observed by X-ray Absorption Spectroscopy” *Journal of the Physical Society of Japan* **82** (2013) 124712.

［2］SPring-8 publication ID = 25939
S. Watanabe *et al*.: “Robustness of Quantum Criticality of Valence Fluctuations” *Journal of the Physical Society of Japan* **82** (2013) 083704.

［3］SPring-8 publication ID = 28096
N. Kawamura *et al*.: “High Pressure Properties for Electrical Resistivity and Ce Valence State of Heavy-Fermion Antiferromagnet Ce_2NiGa_{12}” *Journal of Physics: Conference Series* **568** (2014) 042015.

［4］SPring-8 publication ID = 28555
K. Matsubayashi *et al*.: “Pressure-Induced Valence Crossover and Novel Metamagnetic Behavior near the Antiferromagnetic Quantum Phase Transition of $YbNi_3Ga_9$” *Physical Review Letters* **114** (2015) 086401.

［5］SPring-8 publication ID = 28684
T. Watanuki *et al*.: “Thermal Expansion of a Au-Al-Yb Intermediate Valence Quasicrystal” *Solid State Communications* **211** (2015) 19-22.

［6］SPring-8 publication ID = 28685
N. Kawamura: “Study of Electronic and Magnetic States Probed by X-Ray Absorption Spectroscopy under High Pressure” 高圧力の科学と技術 (*The Review of High Pressure Science and Technology*) **25** (2015) 38-48.

［7］SPring-8 publication ID = 30041
S. Watanabe *et al*.: "*T*/*B* Scaling in β-$YbAlB_4$" *Journal of the Physical Society of Japan* **83** (2014) 103708.
［8］SPring-8 publication ID = 30042
K. Miyake *et al*.: "Unconventional Quantum Criticality Due to Critical Valence Transition" *Journal of the Physical Society of Japan* **83** (2014) 061006.
［9］SPring-8 publication ID = 30043
T. Terashima *et al*.: "X-ray Absorption Spectroscopy in the Heavy Fermion Compound α-$YbAlB_4$ at High Magnetic Fields" *Journal of the Physical Society of Japan* **84** (2015) 114715.
［10］SPring-8 publication ID = 30044
S. Watanabe *et al*.: "Wide Quantum Critical Region of Valence Fluctuations: Origin of Robust Quantum Criticality in Quasicrystal $Yb_{15}Al_{34}Au_{51}$ under Pressure" *Journal of Physics: Conference Series* **592** (2015) 012087.
［11］SPring-8 publication ID = 30046
S. Watanabe *et al*.: "Quantum Criticality and Emergence of the *T*/*B* Scaling in Strongly Correlated Metals" *Journal of Magnetism and Magnetic Materials* **400** (2016) 13-16.
［12］SPring-8 publication ID = 30047
T. Terashima *et al*.: "Synchrotron X-ray Spectroscopy Study on the Valence State and Magnetization in α-$YbAl_{1-x}Fe_xB_4$ (x = 0.115) at Low Temperatures and High Magnetic Fields" *Journal of Physics: Conference Series* **592** (2015) 012020.
［13］SPring-8 publication ID = 30072
F. Honda *et al*.: "X-ray Absorption Spectroscopy and Novel Electronic Properties in Heavy Fermion Compounds YbT_2Zn_{20} (T: Rh and Ir)" *Journal of Physics: Conference Series* **592** (2015) 012021.
［14］SPring-8 publication ID = 30606
Y. Sakaguchi: "Structural Properties and Electronic States in Heavy Fermion $YbAlB_4$ Under High Pressure" Doctor Thesis (University of Hyogo) (2016).

― 課題3 ―

課題名	Phase Contrast X-ray Imaging of the Lung
実験責任者(所属)	Stuart Hooper (Monash University)
採択時課題番号	2012B0047
ビームライン	BL20B2
利用期間/配分総シフト	2012B～2015A/111シフト

［評価結果］

In this long-term project, the group led by Prof. Hooper worked on new-born rabbits and studied changes in the pulmonary system that occur at birth. Several scientific goals had been set such as (1) optimizing the use of sustained inflation for aeration of the lung, (2) investigating mechanisms of increase in pulmonary blood flow that accompanies lung aeration, (3) optimizing resuscitation and ventilation in neonates with congenital diaphragmatic hernia, (4) developing and improving image analysis techniques to estimate regional lung air volume more accurately. Although it seemed in the beginning that there were too many tasks to tackle, the group successfully obtained valuable results in all of these studies and made other additional findings as well. These have been published in 18 papers in both medical and physics journals and more are being prepared. The key to their success was to make best use of coherent X-rays of BL20B2. Although the results were highly controversial, the high quality of the images, available only by using SPring-8, made them acceptable to the medical people and helped improve resuscitation techniques worldwide. For this international collaborative research, the group included physicists, biologists, engineers and clinicians. The project also helped several students to get degrees. Judging from its influences and publications, the project can be not only considered highly successful but regarded as one of the best scientific studies made by fully utilizing potentials of SPring-8.

［成果リスト］

(査読有論文)

［1］SPring-8 publication ID = 25916
S. Hooper *et al*.: "Establishing Functional Residual Capacity in the Non-breathing Infant" *Seminars in Fetal and Neonatal Medicine* **18** (2013) 336-343.

［2］ SPring-8 publication ID = 25920
A. Leong *et al*.: "Measurement of Absolute Regional Lung Air Volumes from Near-Field X-ray Speckles" *Optics Express* **21** (2013) 27905-27923.

［3］ SPring-8 publication ID = 25921
S. Hooper *et al*.: "Expired CO_2 Levels Indicate Degree of Lung Aeration at Birth" *PLoS One* **8** (2013) e70895.

［4］ SPring-8 publication ID = 25972
R. Carnibella *et al*.: "Decoding the Structure of Granular and Porous Materials from Speckled Phase Contrast X-ray Images" *Optics Express* **21** (2013) 19153-19162.

［5］ SPring-8 publication ID = 30092
M. Kitchen *et al*.: "X-ray Specks: Low Dose *in vivo* Imaging of Lung Structure and Function" *Physics in Medicine and Biology* **60** (2015) 7259-7276.

［6］ SPring-8 publication ID = 30093
A. Leong *et al*.: "Real-time Measurement of Alveolar Size and Population using Phase Contrast X-ray Imaging" *Biomedical Optics Express* **5** (2014) 4024-4038.

［7］ SPring-8 publication ID = 30094
R. Carnibella *et al*.: "Single-shot X-ray Measurement of Alveolar Size Distributions" *Proceedings of SPIE* **9038** (2014) 90380V.

［8］ SPring-8 publication ID = 30095
J. Lang *et al*.: "Increase in Pulmonary Blood Flow at Birth: Role of Oxygen and Lung Aeration" *The Journal of Physiology* **594** (2016) 1389-1398.