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Bilateral International Exchange Program (BIEP, invite) report

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(Year/Month/Day)___2010/07/29

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Research Project

Title	Quasiparticle states in exotic superconductors
Duration	2010/04/16-2010/07/30

The three months stay in the group of Prof. Y. Matsuda and Prof. T. Shibauchi were a great opportunity of scientific and cultural exchange between students.

I joined K. Hashimoto, R. Katsumata and S. Tonegawa in the final steps of the building up of a tunnel diode oscillator for the precise measurement of the superconducting penetration depth. My first efforts were to check an expression for the calibration factor given in literature [1], which failed to describe our results. Then I tried an alternative, numerical approach to obtain it more directly and more accurately. Despite surprisingly well agreement with some experimental results, the errors are still appreciable and I (we) hesitate to trust the numerical computations fully. Finally we decided to simply measure the calibration factor on a conventional superconducting sample of the same shape.

A very interesting part of my stay has been the measurement of the London penetration depth in the heavy fermion superconductor URu_2Si_2. This material has enjoyed a great deal of interest over the past 20 years due to a "hidden order" transition at 17.5 K. The order parameter of the new phase still remains undetermined. Below 1.4 K superconductivity develops whose exotic form has been a subject of recent investigations [2],[3].
We could extract from our measurements the penetration depth both for currents flowing in the ab-plane and perpendicular to it. My main contribution was to show that we can describe our data remarkably well by a 2-band model with anisotropic, nodal gap functions as advocated in Ref. [2]. There is also a sensitivity to the gap structure which allows to discriminate between different forms of it. Finally, we include Fermi-liquid corrections as proposed in [4] generalizing the equations to arbitrary band structure as in the former model. This expanded model seems to describe our data even better, even though some ambiguities remain.

A second and parallel project was the measurement of the superconducting penetration depth in heavy-ion irradiated samples of the iron-pnictide compound $BaFe_2(As_{0.67}P_{0.33})_2$. For this we first employed the microwave cavity perturbation method which also yields an absolute value of the penetration depth. However, the measurements cannot be performed down to very low temperatures. So we additionally measured the penetration depth with the tunnel diode oscillator. We find that the critical temperature is (nearly) unaffected by irradiation and the low temperature dependence of the penetration depth seems to change to a higher power law, as opposed to the linear T-dependence observed in pristine samples. Nevertheless, all these measurements encountered difficulties related to the small size of the samples which limit the conclusions we can draw and further measurements on crystals of better quality are needed.

I was both an honor and a great pleasure to stay at Kyoto University and to share the life and work of the students. Doing measurements together, discussing results, attending seminars together, or simply chatting about the different educational systems and lifestyles of our countries, all these were moments of companionship and exchange as was the sightseeing done together. Also, we all became aware of the differences and the respective (dis-) advantages of our educational systems.

A highlight at the end of my stay was clearly the Summer Seminar of the Lab. It was a great pleasure and offered the possibility to get in touch with one another even better. My presence motivated most students to make English slides for their presentations and sometimes even a (partly) English presentation for which I am very grateful. All this gave the seminar a more international atmosphere and gave me the chance to see more of Japan and Japanese lifestyle.

The language was clearly one of the most difficult items of my stay. Since I could not master more than the most basic Japanese expressions I needed help for many elements of daily life and had to rely on people translating for me. I could feel how speaking English became more natural for many students. I suppose my presence also increased their sensitivity to the problems of foreigners. Having shown them that all these difficulties can be overcome, the conclusion may be that even a very young student at the beginning of his/her career needs not to be afraid to go overseas for a while. In this respect, I am sure most students experienced that one's English needs not to be perfect, in order to be sufficient for daily communication. This removes further barriers to go abroad. It might be much more conceivable now.

I would like to express my gratitude towards T. Shibauchi, for welcoming me here, towards everybody in the Matsuda Lab. for letting me become part of them and towards the GCOE for making this stay possible.

[1] R. Prozorov, *et al.* Phys. Rev. B, **62,** 115 (2000).
[2] Y. Kasahara, *et al.* Phys. Rev. Lett. **99,** 116402 (2007).
[3] R. Okazaki, *et al.* J. Phys. Soc. Japan, **79**, 084705 (2010).
[4] C.M. Varma, *et al.* Phys. Rev. Lett. **57**, 626 (1986).