1 Publishable summary (2 pag.)

Project objectives

EXSTASY (**EX**perimental **ST**ation for the **A**nalysis of the **S**pin d**Y**namics) is an FP7-People-2012-International Incoming Fellowship (IIF) Action that provides financial support to the mobility project presented jointly by the *experienced researcher* Prof. Vladimir N. Petrov from St. Petersburg, Russia (Third Country other than Associated Country) and the Italian *Host Organisation* CNR Istitute Officina dei Materiali (IOM), represented by the *Scientist in charge* Prof. Giorgio Rossi. The overall aim pursued by the Action is to reinforce *research excellence* in the European Research Area and to strengthen the human potential in research and technology in Europe, as well as to attract to Europe the best researchers from the entire world. EXSTASY has endorsed all three of these goals. On the scientific research level, it has aimed to and actually set up an experimental station capable of hosting a novel instrument for femtosecond-resolved three dimensional Spin Polarization magnetometry. On the implementation level it succeeded in bringing to Europe for two years the best leading Russian researcher with expertise and know-how in the field of electron spin analysis and in the development of experimental stations. Lastly, at the training & education level, the fellow was involved in the training of PhD students and post-docs and in the transfer of knowledge.

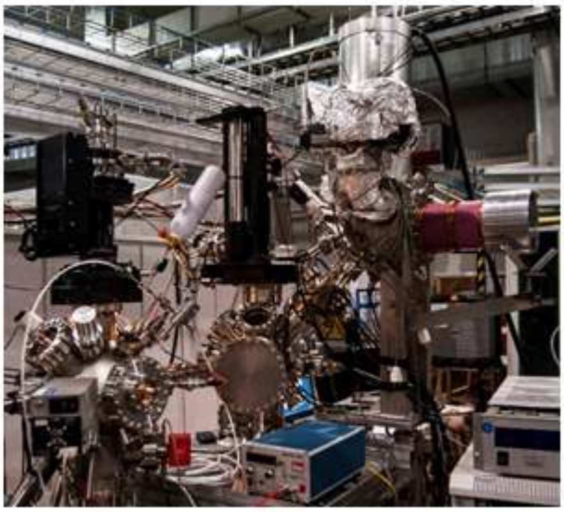
Work performed

<u>Experimental Station</u>

In order to design, build, test and operate the experimental station, the work plan envisaged 5 main tasks that had to be implemented and completed one after the other (some of which representing true technological challenges):

1. A detailed and careful design study and mechanical drawings of the whole vacuum system;
2. Acquisition of the analysis chamber and implementation of the UHV system with the tools needed for performing surface sensitive time resolved experiments;
3. Design study, realization and test of the electron optics;
4. Design, fabrication and test of the electronics for the fast measurements;
5. Preliminary experiments.

The new experimental station is shown in figure1 (left panel). The system is specifically designed to adapt to a large number of experimental conditions, with pulsed sources, from the very low intensities of table-top lasers to the high brilliance of large scale facilities (Free-electron lasers), but also with continuous or quasi-continuous sources (synchrotrons or cw-lasers). The design is essential and consists of two independent spherically-shaped vacuum chambers, lying on the same horizontal plane. One is dedicated to the sample preparation and the second to the spin polarization analysis. The most challenging part of the apparatus is the electrostatic input lens system and a new detector electronics able to measure the spin polarization in a pulsed mode. The input lens system has been optimized by V. Petrov thanks to a careful and accurate simulation work with SIMION program. The system has been successively upgraded by adding a retarding field analyzer section to the electron optics such as to improve the homogeneity of the e-field between sample and accelerator and to allow energy filtering of the collected electrons. Moreover a complete new electronic system has been designed and realized in–house to permit the detection of very short pulse of charge which is not the typical working mode of Mott detectors. To this scope a new architecture of the electronics has been conceived and several components had to be modified or realized ex-novo with custom properties always taking into account the major constraint of the high voltage which is applied to the final part of the Mott detection system. To test this new electronics the fellow had to modify the continuous electron gun apparatus which was present in the hosting laboratory into a pulsed source able to emit pulses of electron as short as 100 ns. Thanks to this apparatus it was possible to test the time resolved working mode of the instrument. In figure 1 (right panel) the comparison between the hysteresis of the spin polarization in continuous and in pulsed mode is shown. The sample used was a 20 ML thick Fe film deposited onto a clean Si(100) surface. The result, apart from the difference in the statistics of the measure, clearly demonstrates that the instrument is now capable of measuring the spin polarization of ultra-short electron bunches thus demonstrating the success of the project.



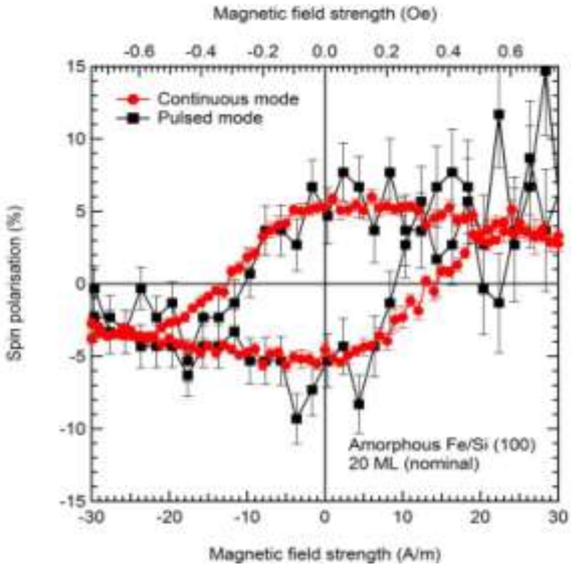


Figure 1: (left panel) The experimental station, the two spherical UHV chamber are visible together with the Y shaped spin detector. (right panel) Spin polarization hysteresis from a 20 ML Fe evaporated on Si(100) sample.

Training and Dissemination

During the two-year life span of the project the fellow undertook several actions to disseminate the state of art of the project and the related results. In particular he participated to 6 different international conferences in occasion of which he gave 5 talks and 1 invited talk on spin resolved related phenomena and co-authored 2 scientific articles on related topics. Within the framework of the visits@Elettra program – a program welcoming several hundreds of visitors each year – Prof. Petrov presented the new EXSTASY experimental station to different groups of visitors (mainly university students from abroad).

Main results and impacts

The most tangible result achieved so far is the novel experimental system suitable for femtosecond time resolved magnetization studies on surfaces and nanostructure, designed to exploit the properties of FEL and XFEL radiation. The apparatus is immediately available for experiments and it is also accessible by international users in the framework of the NFFA-Trieste facility (http://www.trieste.nffa.eu/) (https://www.youtube.com/watch?v=ERWEQOqgnus). Access to this instrument will also enable young scientists to acquire new and scarcely available competences and skills. This is the long-lasting outcome of the training work and know-how transfer by the Russian fellow to the host group.

Potential future impact will depend also on the results of the experiments conducted with this system. Positive results may lead to the expansion of knowledge in the sector of physics (i.e. magnetization dynamics) that is interesting both for fundamental spintronics science and further applications and developments with potential socio-economic impacts.

The transfer of knowledge from the fellow to the host group (Piero Torelli and Giancarlo Panaccione) has been continuous thanks to the discussions between the fellow and the permanent staff on all the relevant issues of the project. Moreover during the second year of the project fellow Prof. Petrov has worked in close connection with a physics degree student (Tommaso Pincelli) which has written his Laurea Magistrale thesis (Università di Modena) on the improvement of the experimental station. The student is now engaged in a PhD project (Università di Milano) in the APE group ensuring the continuity of action.