I SYNTHESE du PROJET

Titre : **ANTARES (A New Tailored Angle REsolved Spectroscopies beamline)**

« A Low-energy Light Source for Electronic and Structural Studies in Condensed Matter »

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Abstract

This beamline has been designed for a complete electronic structure determination using ***spin-and-helicity angle-resolved photoemission*** spectroscopy combined with a local structural characterization by means of ***Photoelectron Diffraction (PED)*** through its both modes, Forward scattering and Backscattering energy regimes. The central part of the project is focused on a finely tuned ***Fermi Surface Mapping study*** of crystalline complex materials. The beamline consistently satisfies the conditions of a high-energy resolution and high-flux source of photons at the focal point, where a 5-axis high precision programmed manipulator controls the sample temperature from 20 to 1000 K as well as its azimuthal and polar position, with high precision.

Caractéristiques Principales de la ligne

Source	**Gamme d'énergie**	**Principe du schéma optique**	**Résolution spectrale (E/ΔE) et flux dans la tache focale (HxV)**	**Stations expérimentales**
Onduleurs HU256 et HU60 à polarisation accordable linéaire et circulaire	**10 eV-1000 eV**	**Monochromateur tranféré de LURE, avec fente d'entrée, 6 réseaux plans (technologie multipiste) et 3 miroirs sphériques branche de sortie rénovée : refocalisation par système « Wolter » avec 2 miroirs (sphérique et torique)**	**10000 sur toute la gamme, 25000 à basse énergie 10^{13} Ph/s dans 300x300 μm^2**	**Une chambre d'Analyse (tranférée LURE) pour la cartographie de surfaces de Fermi (analyseur mobile), la photoémission avec analyse de spin, manipulateur 5 axes haute précision, basse température. Une chambre d'Analyse pour spectroscopie de photoélectrons à haute résolution (analyseur SCIENTA R4000 ou similaire) Les deux chambres, placées sur une plate-forme mobile sont reliées par un système de transfert d'échantillons**

Introduction

The main aim of this proposal is to build a state-of-the-art beamline capable of performing a fine electronic and a local structural characterization of advanced materials, which is intended to serve a broad community of condensed matter scientists extending well further than the existing Large Installation specialist groups. This program includes ***spin-and–helicity angle-resolved photoemission*** mainly devoted to ***Fermi Surface Mapping*** studies combined with a local structural technique as ***Photoelectron Diffraction (PED)*** in its both energy regimes, ***Forward scattering and Backscattering modes***. The main area of application covers the study of highly correlated systems, bulk complex materials as well as magnetic and non-magnetic surfaces, interfaces.

The electronic structure characterization currently achieved by high-resolution core level and valence band photoemission spectroscopy will be refined by a heightened Fermi Surface Topology determination of the investigated materials. It is well known that the electronic structure near the Fermi energy is one of the most direct factors determining the macroscopic properties of condenser matter, such as electric conductivity, magneto-resistance, thermal conductivity, as well as those wide-ranging magnetic properties of metallic systems. Consequently, it is evident that a precise understanding of the electronic states near the Fermi energy is necessary for bringing to light the basic mechanisms responsible for most of the existing condensed matter puzzles. Among the various experimental techniques able to probe the electronic states near the Fermi level, spin-and-helicity angle-resolved photoemission is the unique direct method for mapping out all quantum numbers of these occupied electronic states. Complementarily, the electronic structure characterization of investigated materials will be "in situ" accomplished by a powerful local structural technique as scanned energy and angular Photoelectron Diffraction at high (>400 eV) and low (<400 eV) photoelectron kinetic energy regime. The standard PED structural analysis commonly based on the simplest integrated photoemission spectroscopy will be very much developed by using a spin and high-resolution detection system in addition to a helicity discriminated light source.

Available techniques

The beamline will be suited for the following experimental techniques.

- ***Fermi Surface Mapping***
- ***Scanned Energy and Angular Photoelectron Diffraction***
- ***Angle-Resolved Photoelectron Spectroscopy (ARPES)***
- ***High Resolution Photoemission***
- ***Spin Photoelectron Spectroscopy***

Scientific Case: Fermi Surface Mapping

In the past decade, much experimental and theoretical effort has been devoted to investigate the electronic properties of novel complex and low dimension materials. These systems exhibit often amazing effects, such us Kondo resonances, heavy Fermion behavior, high temperature superconductivity, giant magneto-resistance, oscillatory exchange coupling, magnetic quantum well states, and giant magnetic anisotropy. Lately, due to the remarkable performance gained by Photoemission spectroscopy, this technique has turned out to be considered as almost the unique method to acutely probe tiny and specific electronic properties characteristic of such peculiar behaviors. In this field, the Fermi Surface Topology plays a crucial role. The symmetry, type and density of states at the Fermi energy give direct information on the nature and degree of electronic correlations present in these advanced materials. As in photoemission, both peak position and line width are measured; ***the high-energy resolution*** is vital for studying acutely electronic band structures and Fermi surface topologies. Lately, this has been nicely demonstrated, for example, in the study of superconducting gap of high Tc superconducting compounds (HTSC).

High angular resolution detection is essential. For large unit cell systems, such as C60 and similar compounds, large surface reconstructions and low-symmetry systems, the irreducible reciprocal Brillouin zones are dramatically small. Thus high angular resolution is needed to achieve the necessary momentum resolution to unravel the complete electronic band dispersion comprised in a photoelectron emission angle as small as a few degrees. For this important reason, this type of studies cannot be achieved by traditional spin selected photoemission with a photoelectron acceptance angle of several degrees. The same limitation is suffered by High-energy spectroscopies as X-ray photoemission, which is unable to scan with enough precision small primary Brillouin zones. Moreover, for states near the Fermi energy, low-energy photoemission experiments with high angular resolution can identify in a direct way whether the electronic states disperse across the Fermi energy or stay dispersionless as those localized (correlated) states, which cannot contribute to macroscopic properties as significant as thermal and electrical conductivity or magnetic ordering.

Spin-and-helicity angular discrimination is also fundamental Since the beginning of electronic structure studies by photoelectron spectroscopy, the relevance of measuring the spin polarization of emitted photoelectrons in addition to their angular and energy distributions has been widely recognized. Even though much work has been done during the last three decades, the efficiency of the spectrometers for spin-polarized determinations still remains very low if compared to that of similar apparatus for spin-integrated experiments, because spin polarimeters should use very low efficiency scattering processes. Fortunately, thanks to recently remarkable performance of photoemission instrumentation, there are already available stable, compact and well-fitted Mott-detectors, which are compatible with typical High-resolution angle resolved photoemission setups. These factors make possible to envisage the present ambitious spin-and-helicity discriminated Fermiology project at Soleil.

Photoelectron Diffraction

Photoelectron Diffraction (PED) is an excellent tool to unravel local structure of atoms and molecules adsorbed or burred at surfaces and interfaces. Lately, the power and usefulness of PED technique has been dramatically enhanced by third generation synchrotron radiation sources. The high photon flux and brilliance guarantee a fast acquisition process of very large PED data sets, which ensures a structural analysis of much better quality. Also, the chemical specificity of PED, one of its more important advantages compared to other diffraction techniques, can be considerably improved by a high-resolution photoemission beamline.

Moreover, a spin angular resolved detection together with a polarized excitation source ensures the extension of this structural technique to advanced materials where the local structure around each chemically distinctive species could be resolved, even if they present only different magnetic entourages. As it is well know, any PED modality requires the detection of core level photoemission peaks and their intensity variations as a function of detection angles or incident photon energy. Consequently, detecting spin discriminated core levels with high energy resolution will allow performing precise structural PED determinations of emitters even with minor differences of their structural or magnetic environment. The ANTARES setup at LURE has been particularly adapted to perform complementarily high and low-energy PED. Energy and angular scanned PED can be currently done automatically, at the same end station. Consequently, the envisaged upgrading of the present PED project at Soleil is built on a spin-and-helicity discriminated instrumentation.

Applications

The versatility of the proposed beamline-end stations would make possible to achieve rather different and complex scientific projects, whose feasibility will obviously depend on the dynamism and vitality of the scientific community, developed at and around Soleil. Hence, it is nearly not possible to describe all those promising subjects or potential projects able to be accomplished in the context of the upgraded ANTARES beamline at Soleil. Consequently, in the follow, we will just concentrate on a few selected scientific subjects, which are closely associated to our user community.

High-Tc superconductors and other Complex Materials

The electronic differences between the superconducting and normal state of the HTSC is one of the most debated subject in Solid State Physics. Because it is considered as an important step achieving a deep understand of the basic superconductivity mechanisms present in superconducting materials. Moreover, as the parent compounds of the superconducting materials are Mott insulators, a systematic study of the electronic properties of HTSC as a function of doping level is of vital importance for this field. One of the fundamental questions rose recently theoretically and experimentally is in which extend the magnetism would be concurrent or competitor in superconducting materials. Accordingly, high resolution and spin-and-helicity angle resolved photoemission spectroscopy is a very much effective technique for probing the spin dependence of particularly those electronic states close to the Fermi energy, which are mainly participating on the superconducting transport.

Low dimensional systems

Layered compounds as partially doped graphite substrates and transition metal dichalcogenides are concentrating a lot of interest from a theoretical and experimental point of view. They are considered as prototypes of low dimensional systems where electronic instabilities mainly driven by particular Fermi Surface Topologies play an essential role. In this field, forthcoming studies are focused on the development of spin-and-helicity angle resolved photoemission identifying the spin and symmetry of the electronic states at the Fermi Surface, which are responsible of the 1-Dimensional metallic character of these complex materials.

Surfaces, interfaces and nano-objects

The origin and essential skillfulness of ANTARES group at LURE have been always closely related to the study of surfaces, interfaces and objects of two or even lower dimensionality. Lately, this field has experimented a drastic and fruitful transformation, which has triggered on the right track modern nanotechnology. In addition to the traditional surface studies, an important branch with a rapidly growing interest is concerned with dynamical effects at surfaces and interfaces. It has been noticed in several pure semiconductor surfaces and metal-semiconductor interfaces strong dynamic effects driving complex phase transitions, which modify their electronic and geometrical properties. Recently, many groups in US and Europe have performed numerous indirect studies of those involved systems, however, most of theoretical predictions suggest that spin and charge unbalance at the valence band may be responsible of this atypical behavior. Hence, spin-and-helicity angle resolved photoemission would provide direct inestimable insight into these essential problems affecting this field.

Community potentially interested

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* ***Jose Fontcuberta*** Instituto de Ciencia de Materiales de Barcelona, Spain.
* ***R. Suryanarayanan and Alexandre Revcolevski*** from the Laboratoire de Physico-Chimie de l'Etat Solide at the Campus of Orsay.
* ***Genda Gu*** from Physics Department of Brookhaven National Geographic, USA.
* ***Eugenio Coronado*** Dpto. de Química Inorgánica, Universidad de Valencia.
* ***Stuart Abell*** from School of Metallurgy and Materials, Birminham University, England
* ***Arun Bansil and Robert Markiewicz*** from Northeastern University, Boston, USA.
* ***Matti Lindroos*** from Tempere University , Finland.
**** Pablo Esquinazi***, Institut fur Experimentelle Physik, Superconductivity and Magnetism, Leipzig-Germany
* ***P. Pfeuty and O.Onnufrieva*** from the Laboratoire Léon Brillouin ,CEA-Saclay.
* ***Hervé Guyot*** and the LEPES team from Grenoble.
* ***Veronique Brouet*** and ***Andrés Santander*** from LPS at the Campus of Orsay..
* ***Enric Canadell***, Institute of Material Science of Barcelona, Spain and
* ***Mike Whangbo,*** North Carolina State University, USA.
* ***Sylvie Rousset from the*** *Groupe de Physique des Solides, Universités Paris 6 et 7.*
* ***Jean Marc Themlin and Guy LeLay,*** Marseille group from the Faculté des Sciences de Luminy and Departement de Physique, Marseille at the CRMC2-CNRS.
* ***Massimo Sancrotti*** TASC-INFM, Trieste
* ***José González-Calbet,*** Dpto de Química Inorgánica, University Complutense of Madrid, Spain.
* ***Alfredo Segura*** and ***Juan Sanchez*** from Dpto. de Física, Valence University, Spain.
* ***Ulf Karlsson*** and ***Mats Göthelid***, from the KTH at Stockholm, Suede.
* ***Hugo Ascolani and Silvina*** from the Centro Atomico Bariloche, Argentina
* ***A. Cricenti***, Instituto di Struttura della material di Roma.
* ***Phil Woodruff '***s team from Warwick University in England.
* ***Maria-Grazia Betti*** , Universita` di Roma La Sapienza

II Recommandations du Comité scientifique consultatif (22/01/02)

Beamline Proposal 6 : proposal presented by Maria Carmen Asensio **.**
Transfer and upgrade of the ANTARES beamline from LURE to SOLEIL
Ajouter titre de la ligne

The SAC recommends the transfer of the beamline on an undulator optimized for the low energy part of the project.
The group working now at SuperACO has led the Fermi surface mapping at the highest level of potentiality for electronic characterisation of high Tc cuprates, manganites, 2D and 1D conductors. The scientific project on SOLEIL is focused on the same domain of solid state physics and materials science (where the international competition is strong), with an opening to the study of artificial nanostructures. The size of the users community is large and will undoubtedly be increased at SOLEIL.
The SAC recommendations are :

- Clarify the main goal of the beamline, it is feared that a broad range of techniques and subjects may lead to compromise on the ultimate performances. Thus focus on the Fermi surface mapping, and really optimise the beamline for the low photon energy domain (best possible brilliance, energy and angular resolution).
- Optimize the undulator-monochromator scheme to have a good harmonic rejection
- Precise the design of the end station. The actual small, moveable angle resolved analyser mounted on a goniometer is state of the art in the domain and should be maintained.
- In the future, spin analysis has to be introduced. The feasibility of combining high energy resolution, moveable analyser and spin detection seems difficult. Here again a coordination at the level of the SOLEIL directorate should be considered for spin resolved experiments.
- The status of this beamline relative to the Spanish community should be clarified as quickly as possible.

III Propositions de la Direction de SOLEIL

La direction de SOLEIL demande l'aval du Conseil pour le lancement du tranfert de la ligne ANTARES à SOLEIL. Le schéma de ligne proposé permet d'optimiser le transfert d'éléments de la ligne franco-espagnole SU8 de LURE sans compromettre les performances de l'ensemble. Cette ligne de photoémission dotera la communuaté scientifique d'outils d'analyse complémentaire à ceux développés sur les autres lignes de photoémission : l'accent est mis sur la détermination extrêmement fine de la structure eléctronique des matériaux au voisinage du niveau de Fermi (cartographie de surface de Fermi, photoémission haute résolution en énergie et en angle, analyse de spin). La gamme d'énergie proposée (10-1000eV) permet de répondre aux besoins et de disposer d'une source monochromatique très performante (réjection d'harmoniques, polarisation accordable). Cette ligne permettra de répondre à des questions fondamentales posées lors de l'étude des supraconducteurs à haute température critique, les isolants de Mott, ou les systèmes de dimensionnalité réduite.