Nano-XEOL using near-field detection

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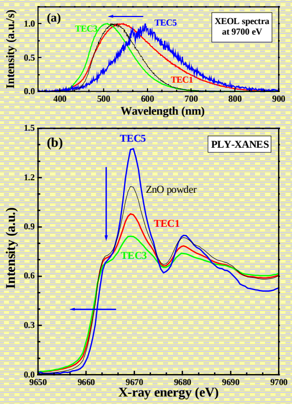
Abstract

The WP2 of the X-TIP project aims to deliver a new instrument to detect the X-ray Excited Optical Luminescence (XEOL) signal by means of the optical fiber tip of a Scanning Near-Field Optical Microscope (SNOM). The goal is to merge the capabilities of local probe microscopies with the potentialities of synchrotron radiation spectroscopies, performing nano-XEOL measurements. A fully working SNOM prototype has been developed. Big efforts were directed to the fabrication and characterization of SNOM tips for XEOL detection.

XAS-XEOL



Generally, **X-ray absorption spectra** (XAS) probe the short-range around all absorbing atoms.

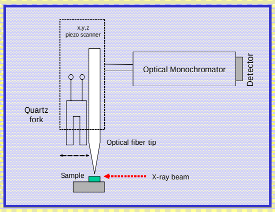
In some selected cases, **XEOL detection mode** is sensitive **only** to changes in the local environment of the luminescent centers. By comparing XEOL-XAS spectra obtained from different regions of the luminescence spectra and XAS spectra collected with other detection modes, it is possible to characterize the absorbing centers directly related to the light emission properties.

Detecting the XEOL signal using a SNOM tip, we hope to perform:

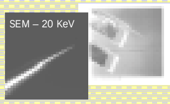
1. simultaneous imaging and spectroscopy at a fixed X-ray energy;

2. XAS-XEOL measurements with nano-resolution, scanning the incident X-ray beam energy

SNOM



General mechanism: the probe is raster scanned very close to the sample. It can work as illumination source or to collect the optical near-field from the sample. In any case, an optical image of the surface is obtained, with a spatial resolution beyond the classical diffraction limit.



Coating equipement (left). Metallized optical fiber tip and SNOM tip glued to the quatrz tuning fork (right)

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Probe: generally it is a tapered optical fiber tip with a sub-wavelength aperture that determines the lateral resolution of the microscope. A metallic coating improves the transmission/collection properties of the tip.

Tip-sample distance control: tip is dithered laterally at one of its mechanical resonances. As the tip approaches the sample, shear forces dampen the amplitude of the tip vibration. The amplitude can be monitored and used to generate feedback signal to control tip-sample gap during imaging.

X-Tip SNOM prototype

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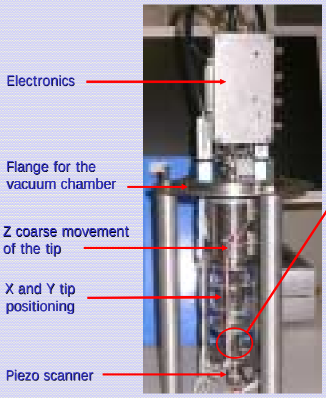
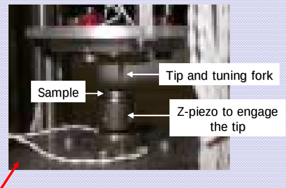
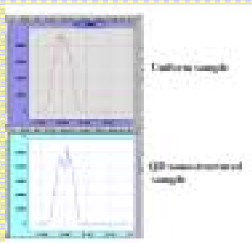




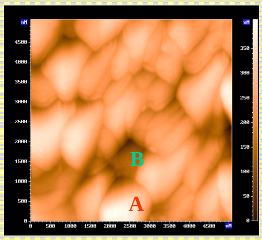
- Collection mode
- Metallized optical fiber tip
- X-Y scanning by the sample
- High precision piezo-inertial movements
- Remote control of the system
- Grazing incidence of the X-ray beam

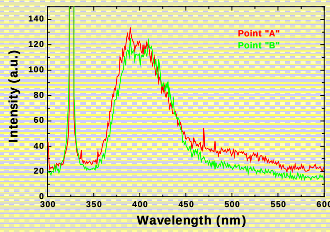
Promising results...

Luminescence distribution under X-rays for an uniform sample and quantum dots buried under Si layer (scanned surface: 5x5 μm^2)



First measurements on a ZnO thin film performed with our SNOM prototype.
Left: topographic image of the surface
Right: luminescence spectra coming from points A and B of the surface (330 nm laser excitation source)





Open problems...

Main problems are related to the collection of light in near-field condition under X-ray excitation:
• intensity and collimation of the X-ray beam;
• stability of the X-ray beam and of the experimental setup;
• absolute alignment;
• intrinsic limitations of lateral resolution;
• long term radiation damage of sample and tip.

Other problems are related to the characteristics of samples under study and to the physics of the light emission under X-ray excitation, in particular:
• balance between penetration depth of X-ray and dimensions of nanostructures to be studied;
• dependence of XEOL intensity from X-ray energy.

Work in progress...

• Optimization of remote controls and high precision movements of the X-TIP prototype.
• Improvement of optical fiber tip fabrication and metallization to obtain better lateral resolution and to maximize light collection.
• Synchrotron radiation experiments on ZnO nanostructured thin films.
• Test the feasibility of tip-enhanced XEOL in apertureless SNOM configuration.