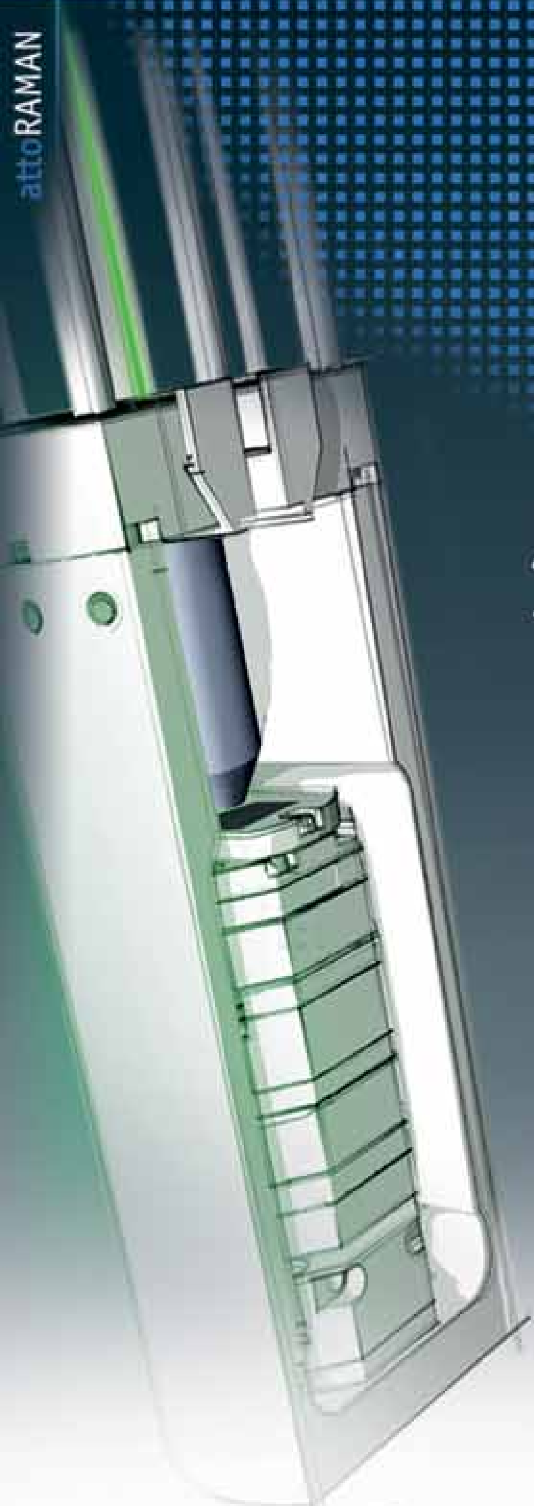
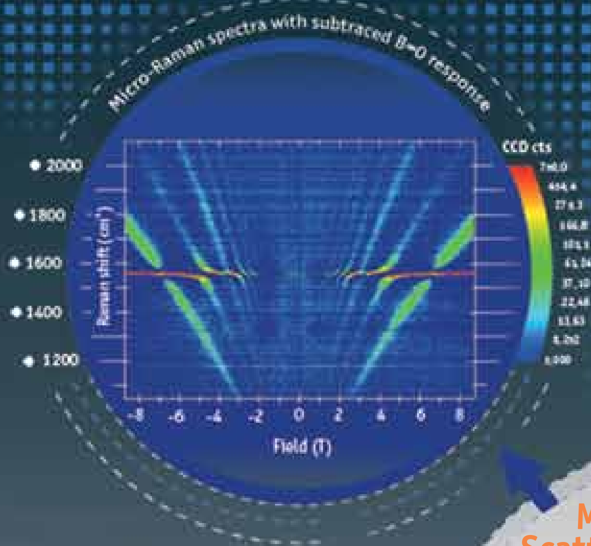
Raman microscopy on GRAPHENE at 4 Kelvin and 9 Tesla



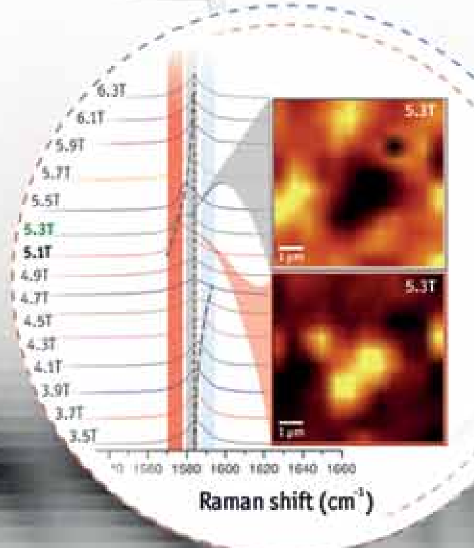


Magneto-Raman Scattering on Graphene

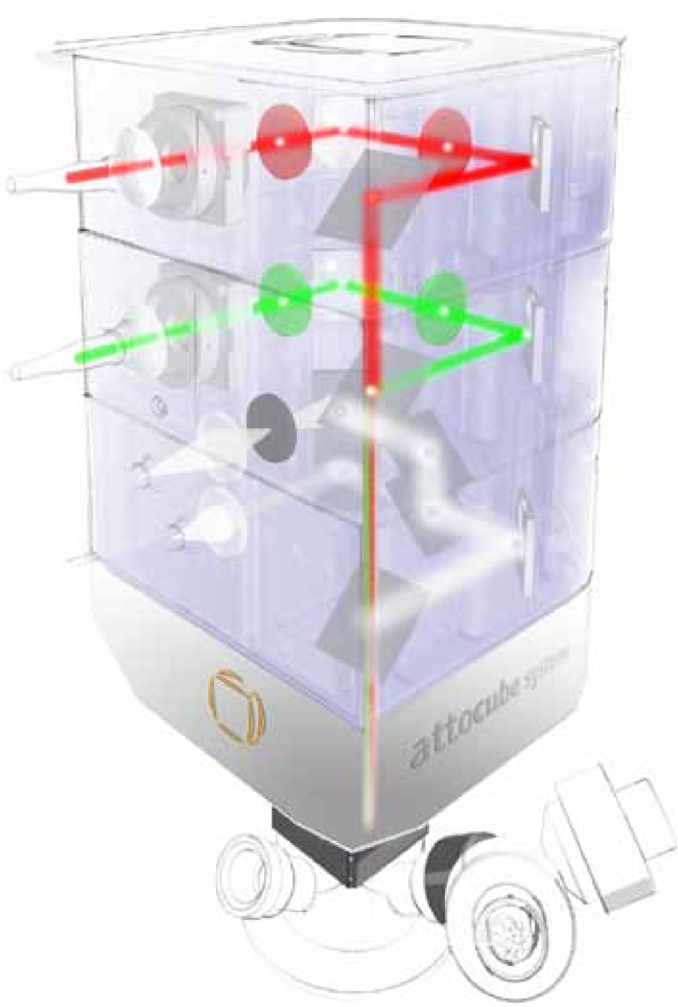
We show magneto-Raman measurements recorded on an exfoliated single crystal of natural graphite, exposed to magnetic fields of up to 9T at 4 K. The data were recorded on a single graphene flake and demonstrate the crossing of the E2g phonon energy with the electron-hole separation between the valence and conduction Landau levels (-N,+M) of the Dirac cone. Resonant hybridization of the E2g phonon is a specific signature of graphene flakes which display very rich Raman scattering spectra varying strongly as a function of magnetic field. [C. Faugeras et al., PRL 103, 186803 (2009)]

Field Evolution of Raman Spectra

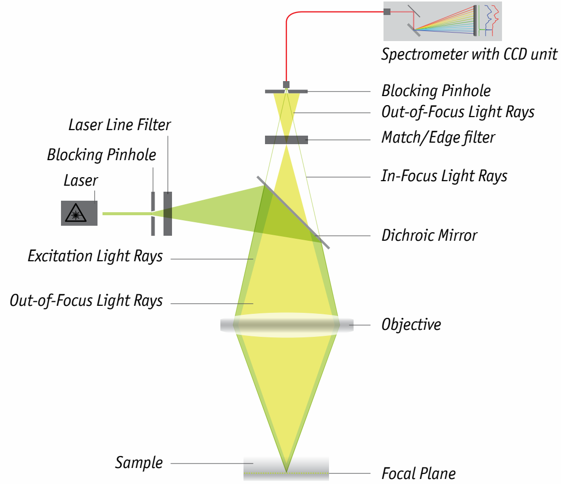
The graph below shows the magnetic field evolution of Raman spectra recorded in a region where the hybridization of E2g phonon and (-2,+1) and (-1,+2) magneto-exciton takes place. We map the Raman scattering signal over 7 x 7 µm² with 600 nm spatial resolution in different scattering bands - namely red-shifted and centered on the E2g phonon peak at 5.3 T. As expected, the graphene flake appears bright in the (lower) red shifted image, but appears darker in the Raman scattering map centered on the E2g peak (upper image).



External Confocal Module



Confocal Microscopy Principle



Confocal Raman microscopy setup

In the attoRAMAN microscope, a laser source is used to illuminate the sample as depicted in the figure above. Standard sources include frequency doubled or tripled Nd:YAG (532 nm, 355 nm) and HeNe (632.8 nm) laser. The laser is focused on the surface using a confocal objective and a blocking pinhole. To reject elastically scattered light from the sample (Rayleigh scattering), the backscattered light is passed through a dichroic mirror and a notch filter. The remaining signal is then passed through a blocking pinhole into a spectrometer, where the Raman spectrum is recorded and analyzed.

Particularily the investigation of high-T_c superconductors (pnictides, cuprates) and other new classes of materials such as Graphene have led to a constant need for Raman microscopy systems being capable of operation at low temperatures combined with high magnetic fields. The attoRAMAN exactly addresses these needs and allows the user to record Raman images and Raman spectra at a broad range of temperatures, ranging from 1.8 K to 300 K, and at magnetic fields of up to 16 T.

In materials with strong electron-phonon coupling, such as Graphene, the attoRAMAN is a very efficient tool to study both mechanical and electronic properties of a sample. A sophisticated software allows to analyze, sort, average, and postprocess spectra, enabling the user to investigate finest details and fingerprints in the Raman signature.

Specifications

Microscope Configuration	confocal unit	modular beam splitter microscope head outside of the cryostat, excitation and collection port fully adjustable, free beam optics, optional polarizer and retarder possible
Sample Positioning	coarse range step size scan range	5 x 5 x 5 mm³ @ 300 K: 0.05 .. 3 µm @ 4 K: 10 .. 500 nm 40 x 40 µm³ 30 x 30 µm³
Operating Conditions	magnetic field range operating pressure temperature range	0 .. 15 T+ (dependent on magnet) 1E-6 mbar .. 1 bar 2 .. 300 K (dependent on cryostat)
Illumination	excitation wavelength range light source light power on the sample port specification optical filter	532 nm, others on request dedicated Raman laser, single mode fiber coupled typically 1 pW .. 10 mW FC/APC-connector for single mode fibers laser line filter
Raman Signal Detection	spectrometer total optical transmission filters gratings pixel resolution	ultra-high tranmsission spectrometer, f=300 mm greater 60% at 532 nm dichroic mirror and edge/notch filter for signal detection as close as 90 cm-1 to the laser line typ. 600/mm and 1800/mm, others on request 1 cm^{-1} at 1800/mm grating