Report on the outcomes of a Short-Term Scientific Mission[1]

Action number: CA20129

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Details of the STSM

Title: Study of high harmonic generation in semiconductors irradiated by an intense mid-infrared ultrashort laser pulse

Start and end date: 18.05.2025 - 31.05.2025

Description of the work carried out during the STSM

The experiment was conducted using the MIR laser source at ELI-ALPS. The MIR source consists of an OPCPA (optical parametric chirped-pulse amplifier) pumped by laser pulses with duration of 1 ps at full width at half maximum (FWHM) generated by a high power laser system including an oscillator with a thin disc Ytterbium-YAG active medium and a regenerative amplifier (Dira200-100 from Trumpf Scientific Lasers), centred at λ=1030 nm. The OPCPA currently delivers pulses of 45 fs FWHM (4.2 cycles), centred around λ=3.2 μm, at a repetition rate of 100 kHz and of maximum energy 120 μJ. This source was used to drive the generation of high harmonics in a solid-state target. High harmonics were generated by the interaction of the intense (≈ 5×10^{11} W/cm^2) MIR pulses with ZnO crystals of thickness 50 and 200 μm with two different crystallographic orientations, and with Si thin films of thickness 50, 100 and 200 nm with one crystallographic orientation.
We used especially developed software to set and control the measurements and record the data from the two different spectrometers, cameras, and motorized rotation stages for the samples and for the half wave plate and quarter wave plate. A manual Z scan was performed as well.
The detection of the high harmonics was carried out using an AVANTES spectrometer and an VUV spectrometer combined with a CCD camera available in the MIR lab. During our experiment, a new grating was commissioned for the VUV spectrometer; the programmable motorized rotational stage for mounting the samples was commissioned as well.
In the first case when using an a-cut ZnO [11-20] crystal, both even and odd harmonic were observed for laser fields polarized along the optical axis. In the second case when using an c-cut ZnO [1000] crystal only the odd harmonic were observed for laser fields polarized along the optical axis. Only odd harmonics were observed in Si thin films for which the laser polarization was along the [100] crystallographic direction.

[1] This report is submitted by the grantee to the Action MC for approval and for claiming payment of the awarded grant. The Grant Awarding Coordinator coordinates the evaluation of this report on behalf of the Action MC and instructs the GH for payment of the Grant.

Description of the STSM main achievements and planned follow-up activities

Most of goals of the experiment were achieved. We have made power scans and polarization scans using half wave plate, quarter wave plate to change the polarization of the driving laser pulses and combination of the two to achieve elliptical polarization. We have successfully measured below-and above-gap harmonic spectra in the chosen semiconductors. The harmonics produced by ZnO are both odd and even depending on the crystal orientation relative to the linear laser polarization. The harmonics generated in Si thin films are exclusively odd since the laser polarization direction coincides with 100-crystal axis. All harmonic spectra show clean and distinct peaks. The orientation dependence of the obtained spectra is strongly pronounced and will be used in conjunction with the theoretical calculations to make conclusions how the specific symmetry and the properties of the electronic band structure of the investigated crystalline solids influence the generated high harmonic spectra. Also a systematic study will be made on the dependence of harmonic yield on crystal thickness.

One of the main achievements of the experimental campaign was the commissioning of the new grating for the VUV spectrometer via which we were able to register harmonics in VUV spectral range.

The results obtained from the experiment will be properly analysed and we hope they will be published in the near future with co-authors from the MIR laser group.