Focus on CSIR research in femtosecond science

CSIR
National Laser Centre
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The femtosecond amplifier

The wavelength-adjustable output of the optical parametric amplifier

Femtosecond Science

The femtosecond science group's vision is to do applied research using femtosecond lasers and related technologies, aimed at solving real-world problems while working at the cutting edge of this new technology. The major focus of this work is coherent control and all activities are directed towards this goal.

Femtosecond science is the field of research and technology utilising state of the art laser systems delivering extremely short pulses with high peak intensities, in particular pulses in the femtosecond regime.

One femtosecond is equal to one millionth of a billionth of a second. This is an extremely short unit of time: small molecules typically take a few hundred femtoseconds to complete one vibration. This is exactly one of the advantages of such short pulses; they are so short that they can be used to measure extremely fast processes, down to the femtosecond regime where no other time-resolved techniques exist. We use this characteristic of femtosecond lasers to measure very fast biological and chemical processes. The next step is to use this technology to actually control chemical and biological reactions, a technique called coherent control.

The femtosecond laser system

Our femtosecond laser consists of a Coherent Mira oscillator (76 MHz, 795 nm, 8 nJ per pulse, 130 fs), which acts as a seed laser for a Coherent Legend regeneratively amplified femtosecond laser (1 kHz, 795 nm, 1 mJ per pulse, 130 fs). The output can be used to pump an optical parametric amplifier (OPA) for frequency conversion to wavelengths in the range 540 nm – 20 000 nm, also in roughly 130 fs pulses with lower pulse energies of 1 – 200 μJ. Integrated into the laser system is a FastLite Dazzler acousto-optic pulse shaper, which is used to generate various different temporal pulse shapes, for example double pulses or chirped pulses.

Femtosecond Science Research Topics

Coherent control

Coherent control principles are being developed in an attempt to ***actually control chemical and biological reactions***. All our research efforts are focused on this goal, as can be seen in the descriptions below.

Femto-chemistry

Femtosecond laser pulses are used to ***study the activation, dissociation and ionisation of various molecules in the gas and liquid phases***. Studies are currently focused on observing ionisation fragments and attempting to change these fragmentation ratios. The eventual goal is to control specific chemical reactions.

Femto-biology

Femtosecond laser pulses are used to study fast biological processes. Current research is focused on the ***measurement of ultrafast energy transfer events in light harvesting complexes***.

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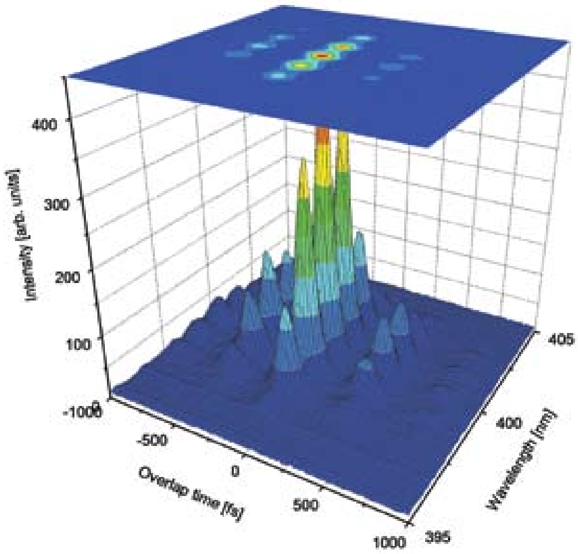

A FROG trace of a complex pulse

Infrastructure and Techniques

(a) Laser and pulse diagnostics

For ***pulse diagnostics***, we have developed a second harmonic generation (SHG) background-free autocorrelator and a frequency resolved optical gating (FROG) based on the same setup. We ***continually improve and develop diagnostic techniques*** for more complex requirements of our other research activities. Other equipment includes a SwampOptics Grenouille device.

(b) Time domain pulse shaping

Pulse shaping is achieved using the FastLite Dazzler pulse shaper, and ***a feedback loop*** is being developed for coherent control, by varying a number of pulse parameters. Furthermore, the shaping capabilities are continuously being ***characterised*** for various applications, as these become necessary.

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(c) Spatial domain beam shaping

Spatial beam shaping is currently in the planning stage, for ***optimising beam delivery*** for various applications, and also for basic studies of the coupling between spatial beam shapes and temporal pulse shapes.

(d) Laser ionisation time of flight mass spectrometry

Femtosecond laser ionisation time of flight mass spectrometry is being used to study complex molecules in the gas phase and can be used as a sensitive diagnostic instrument. We use a home-built reflectron time of flight mass spectrometer for this purpose.

(e) Pump probe spectroscopy

Transient absorption pump probe spectroscopy (at a temporal resolution of about 150 fs) is done in various liquid-phase samples. The tunable output from the OPA is used as pump at various wavelengths in the visible, while some of the fundamental 795 nm laser output is used to generate a white light continuum which is used as the probe pulse. This is done with the CDP ExciPro pump probe system.

Industrial Applications

Laser-induced breakdown spectroscopy

Femtosecond laser-induced breakdown spectroscopy is used as a ***diagnostic tool*** to study the concentration and distribution of various elements in thin layers of solid materials. This technique can be used to determine low quantities down to the ppm level and is potentially a remote / non-contact diagnostic technique, which can be very ***useful in some industrial applications***. We use an Andor Shamrock spectrometer with iStar ICCD camera which has a 5 ns gate width.

Contract research

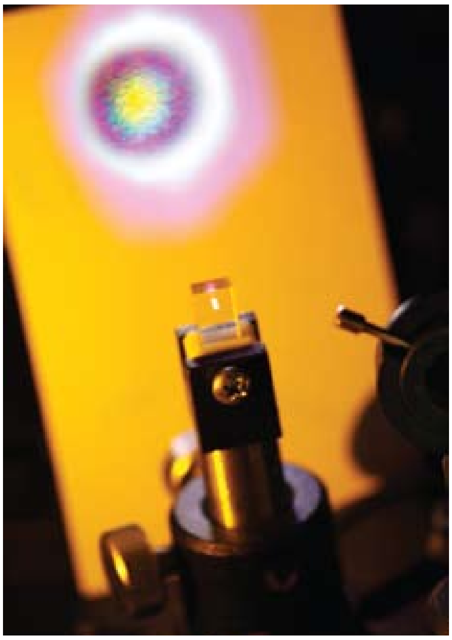
In order ***to ensure that our research makes an impact***, we do contract research in order to solve specific problems using our technology and our infrastructure.

Micromachining

A femtosecond micromachining station is under development for the machining of ***small holes and feature sizes of the order of a few microns***. The advantages of the femtosecond laser for this application are its low heat transfer (and therefore small heat affected zone) and the low mass ablation rates resulting in the small features that can be machined.

Collaborations

We currently have active collaborations with the North West University's Chemistry Department, the CSIR Synthetic Biology group and the University of Stellenbosch's Laser Research Institute.



White light continuum generation in a sapphire plate

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