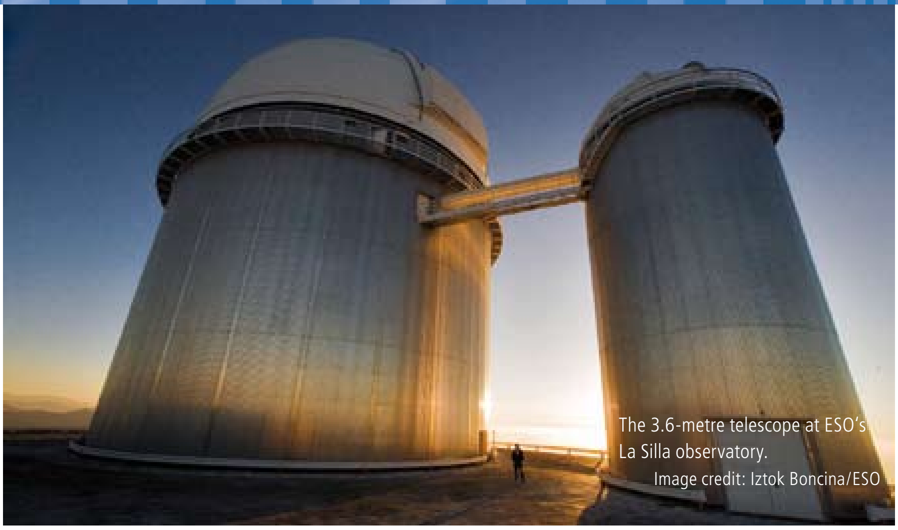
ASTRO COMBS


The 3.6-metre telescope at ESO's La Silla observatory.
Image credit: Iztok Boncina/ESO

MEASURING COSMIC VELOCITIES

Spectrographs connected to telescopes are used to identify planets around stars outside our solar system. Astronomical spectrographs are typically calibrated against Thorium-Argon lamps or Iodine absorption cells. A more precise way of calibration should make it possible to explore deep space more accurate than ever before, making identification of Earth-sized planets or direct detection of cosmic acceleration possible.

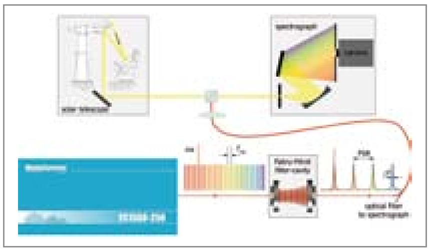
Traditional calibration techniques are subject to uncertainties that unavoidably degrade the wavelength resolution: lines are not evenly distributed in the spectral range of interest, have a wide range of intensities and sometimes appear blended. The frequency comb technology may offer a solution.

A RULER MADE OF COMB MODES

When laser pulses pass through a spectrometer, the regular train of modes is overlapped with the light collected by the spectrograph and hence can be used as a perfect ruler to calibrate the apparatus with unprecedented resolution.

The main challenges are to generate a frequency comb with a sufficiently large mode spacing that can be resolved by the astronomical spectrograph and to have sufficient comb light in the full spectral operating range.

Fabry-Pérot cavities can serve as mode filters to increase the fundamental mode spacing. Using more than one filter cavity has the advantage of achieving a higher suppression of the unwanted modes. Power losses due to the rejected modes of the filter stages need to be replenished to ensure sufficient light intensity for non-linear processes such as frequency doubling and spectral broadening necessary to match the frequency comb spectrum to the optical bandwidth of the spectrograph.


A solar telescope collects light that is superimposed with the frequency comb light. Together they are fed to a spectrometer. Since the original mode separation of the frequency comb (250 MHz) is too close to be resolved by the spectrometer, the light is first filtered using a Fabry-Pérot filter cavity to 15 GHz.

TAILORING THE YTTERBIUM FIBER COMBS

The FC1000-250 Optical Frequency Synthesizer is an ideal choice for such a system. Based on an Ytterbium-doped fiber laser, it allows for amplification to high power levels. The automated ASTRO Extension Package can be configured to meet the individual requirements posed by high performance astronomical instruments in need of high-precision calibration.

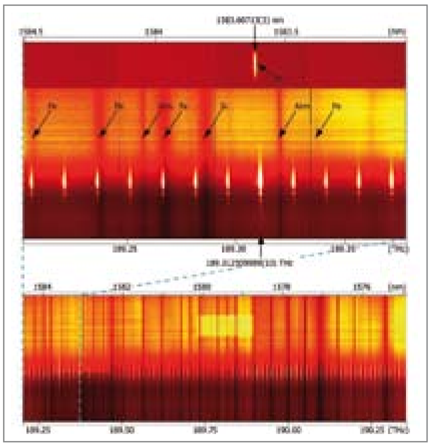
ONE OF ASTRONOMERS' DREAMS FULFILLED

Menlo Systems teamed up with scientists from the Max Planck Institute of Quantum Optics in Germany and the European Southern Observatory to develop calibration instruments

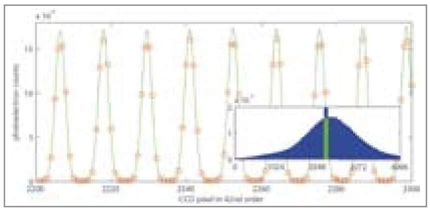

Tilo Steinmetz from Menlo Systems and Constanza Araujo-Hauck set-up the comb mode filter cavity at the VTT optical laboratory, in Tenerife.
Image credit: ESO

specially designed for high resolution spectrographs. After successful tests in the laboratory, in 2008 the team has successfully tested a prototype device using the laser comb at the Vacuum Tower Telescope (VTT) solar telescope in Tenerife, measuring the spectrum of the Sun in infrared light. For more information on this proof of principle campaign see Steinmetz et al. in *Science Vol. 321: 1335-1337, 2008*.

Current work focuses on the calibration of the HARPS planet-finder instrument on ESO's 3.6-metre telescope at La Silla in Chile.
Recently published results by Wilk et al. (in *Monthly Notices of the Royal Astronomical Society Vol. 405: L16–L20, 2010*) announce an era of a promising technique to achieve the accuracy needed to study the big astronomical questions.

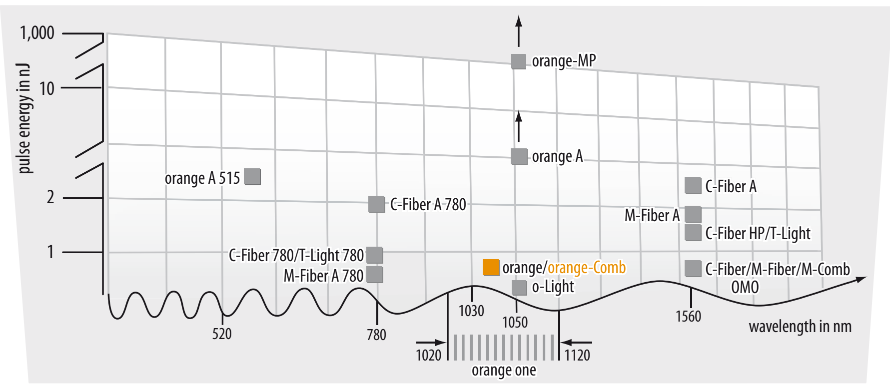


The solar spectrum measured at the VTT on Tenerife. A section is magnified on top; the dark lines are caused by absorption of gaseous elements in the photosphere of the Sun and by absorption in Earth's atmosphere. The spectral lines of the frequency comb appear as bright streaks that are used as precise calibration lines for the entire solar spectrum.



The laser frequency comb calibration spectrum is determined by fitting individual comb modes with Gaussians, which serve as a good approximation of the spectrometer point spread function. A section of the extracted comb spectrum (red dots) is shown together with a sum of Gaussians fitted to the data (green line). The inset shows one full echelle order (out of 72) with the spectral envelope of the frequency comb. The range of the zoomed region is highlighted.

MENLO SYSTEMS' LASER SELECTOR



ORDERING INFORMATION

FC1000-250
Optical Frequency Synthesizer

ASTRO
Extension Package for Mode Spacing in the GHz range