THIS - A Quantum-Cascade-Laser pumped Mid-Infrared Heterodyne Receiver

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A brief description of the current status of the Cologne Tuneable Heterodyne Infrared Spectrometer **THIS** is given. By using quantum–cascade lasers (QCL) [1,2] as local oscillator (LO) **THIS** opens the mid–infrared wavelength region from 5 to 28 μ m for ultra–high–resolution spectroscopy with a system sensitivity equivalent to CO₂–laser based heterodyne instruments [3–6] (noise temperatures about three times the quantum limit of 1440 K @ 10 microns, see fig. 2). The current bandwidth of 1.4 GHz is



Figure 1: Setup scheme of the receiver: QC-laser and signal (switchable between telescope and two loads for calibration) are combined and focussed on the detector. After filtering and amplification the frequency-analysis is done using an AOS.



Figure 2: Comparison between QC- and CO_2 -laser: system performance is equal, above 1000 MHz *i.f.* the performance of the detector drops.

provided by an acousto-optical spectrometer (AOS). The frequency resolution is $R = 2 \cdot 10^7$. (This corresponds to a 14 km/sec bandwidth at a wavelength of 10 microns). **THIS** is the only widely tuneable infrared heterodyne receiver to date.

THIS consists of an optical receiver and common back–end electronics including the AOS. Inside the receiver the QCL is very efficiantly superimposed with the telescope beam on a confocal travelling wave ring-resonator (the diplexer) and mixed on a fast Mercury–Cadmium–Telluride detector (MCT) [7,8]. The performance of THIS using a CO₂–laser LO in comparison with a QCL is practically identical as is shown in fig. 2. A scheme of the receiver is shown in fig. 1.

Various measurements at different ground based telescopes (e.g. the west auxiliary telescope of the McMath–Pierce Solar Observatory near Tucson, Az.) including the analysis of trace gases in the Earth's atmosphere, observations of molecular features in sunspots (see fig. 3), and detection of non–LTE CO_2 emission from the Venus atmosphere (see fig. 4) have been performed. These observations demonstrate the instrument's capabilities with regards to astronomical observatory at both, ground based telescopes and the stratospheric observatory **SOFIA** in the near future.



Figure 3: measurements (black) in a sunspot (11/21/2002) and Voigt-fits (light gray), left: 040-030 15_{1,15}-15_{2,14} transition of H₂O, right: ²⁸SiO 6-5 P(50) absorption at 1088.80925cm⁻¹, Insets: Spectra taken on (black) / off (gray) the sunspot. The SiOspectrum still shows residuals from atmospheric ozone around 600 MHz i.f.

Besides incorporating new laser-technology it is also important to increase the presently available IF-bandwidth of MCT-mixer detectors. Therefore, in collaboration with the Fraunhofer IAF institute in Freiburg, Germany, first experiments with Quantum Well IR-Photodetectors (QWIPs) began [9,10]. Those devices might be able to reach MCT-mixers in terms of quantum-efficiency but will probably provide a significantly larger bandwidth (fig. 5 shows one of the first test measurements). As future backend a Wide-Band-Specrometer (WBS) is currently under development at KOSMA based on the well known AOS-design. It will double the available bandwidth to 3 GHz. Further increase in bandwidth is achieved by stacking several spectrometers in an array-setup.



Figure 4: Non–LTE R(36) transition of CO_2 from the illuminated arc of Venus. The emission is located in the middle of the broad CO_2 –absorption peak. Data are binned to 20 MHz resolution.

Figure 5: First test of a QWIP–detector: the overall performance is still well below MCT–mixers but new developments promise good quantum–efficiencies and large bandwidths.

The long-term goal is the operation of THIS on the stratospheric observatory SOFIA from roughly 2007 on. Here the detection of the two lowest lying pure rotational transitions of cold interstellar H₂ against moderately hot IR sources at wavelengths around 17 and 28 μ m will be the prime target. Moreover since QC-lasers are beeing developed for the THz-regime as well, **THIS** might serve as a prototype for QCL-pumped THz-receivers in the future. [1] J. Faist, F. Capasso, D.L. Sivco, C. Sirtori, A.L. Hutchinson and A. Cho, "Quantum cascade laser" Science **264**, 553–555 (1994)

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