PRECISION FREQUENCY METROLOGY AND STABILIZATION

FOR CONTINUOUS WAVE (CW) THZ SOURCES BASED ON TWO-COLOR LASER MIXING

Th. Kinder, Th. Müller-Wirts, TEM Messtechnik GmbH, Großer Hillen 38, 30559 Hannover, Germany
A. Deninger, TOPTICA Photonics AG, Lochhamer Schlag 19, 82166 Gräfelfing, Germany

Introduction

One method of generating THz radiation is optical heterodyning of two continuous laser fields on a semiconductor photomixer. The advantage of a cw THz source compared to pulsed sources is the fact, that measurements can take place at arbitrarily chosen, fixed or variable THz frequencies for unlimited and uninterrupted time intervals. This allows e.g. for high resolution spectroscopy, or for interferometric distance or a refractive index measurements.

Set-up

The measurements were carried out with the following set-up (fig.3). Two DL-DFB lasers (TOPTICA) are driven by the temperature controller DTC110 and the current controller DCC110. The laser beams are coupled into a 2x4 polarization maintaining fiber combiner, superposing the major part of the input power in common fiber arms. Approx. 1% of each laser input power is tapped off for frequency and power control by an iScan interferometer (TEM Messtechnik) head. For the beatnote measurements, the light from the common ends was focussed onto a 1.6 GHz photo receiver.

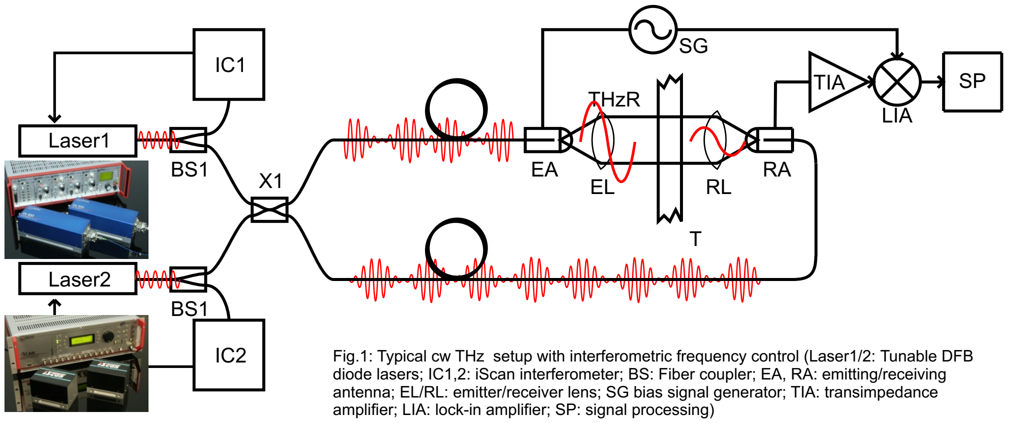


Fig.1: Typical cw THz setup with interferometric frequency control (Laser1/2: Tunable DFB diode lasers; IC1,2: iScan interferometer; BS: Fiber coupler; EA, RA: emitting/receiving antenna; EL/RL: emitter/receiver lens; SG bias signal generator; TIA: transimpedance amplifier; LIA: lock-in amplifier; SP: signal processing)

Principle of Interferometric Frequency control

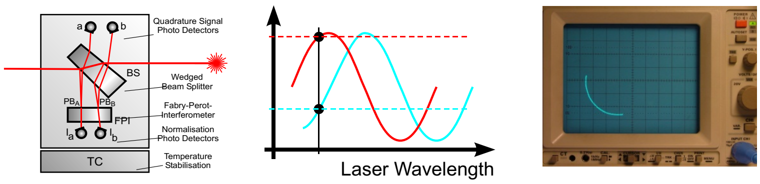


Fig. 2: a) Frequency sensing interferometer design

b) principle of quadrature signals

c) signal on the scope with the laser detuning by 1/4 FSR

A prerequisite for high precision cw THz measurement is the knowledge and preferably the stabilization of the THz frequency.
The heart of the system is a low finesse interferometer (Fig. 2a; U.S. patent no. 6,178,002, German patent no. DE 197 43 493 A1), which generates two interferometric signals. These are sinusoidal functions of the optical laser frequency (fig. 2b). Due to their 90° relative phase shift, the signals are called quadrature signals. If displayed in x/y-mode on an oscilloscope screen, the spot takes a circular path if the frequency changes (fig. 2c). Speaking in polar coordinates, the momentary angle of the X,Y-position is a measure for the optical laser frequency. A full turn around the circle corresponds to a frequency scan of the laser by one Free Spectral Range (FSR) of the iScan interferometer.
In closed-loop servo operation, the actual phase is compared to a computer-generated set value, and the deviation is fed back to the laser under control. The result is a stabilization of the optical frequency to any value within the tuning range of the given laser, *even during a scan*.

Results

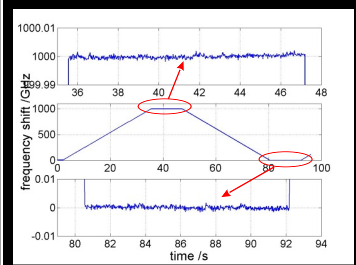


Fig. 3: Large linear frequency scan

One great advantage of an iScan regulated laser is the possibility to perform arbitrary frequency scans with fast settling to the target frequency. Fig. 1 shows the performance of a precisely linear 1000GHz scan with some seconds hold at either end. The target frequency is reached with MHz accuracy without creeping or overshoot.

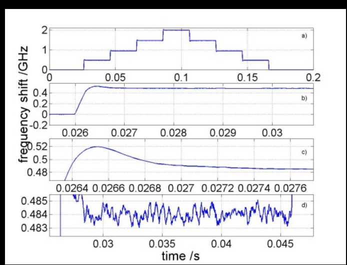


Fig. 4: Step-shaped frequency scans

For determination of the settling time, we scanned the laser by 2 GHz in steps of approx. 500 MHz. The step duration was 10ms.
Fig. 4 shows the whole scan (diagram a) and zoom-ins scaled differently (diagram b…d), revealing the settling behaviour of the first step.

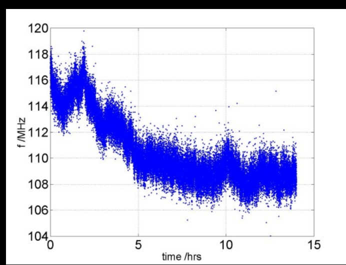


Fig. 5: Long-term stability

We measured the long-term frequency stability by recording the optical beat frequency on a 1.6 GHz photo receiver. The measurement was started at 5:47 pm and lasted for 14 hours. While the room temperature changed by more than one K overnight, the beat frequency changed by about 8 MHz only.

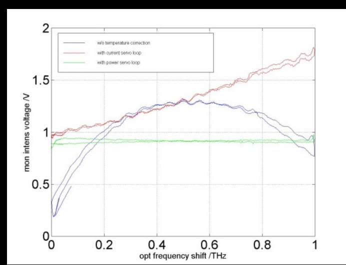
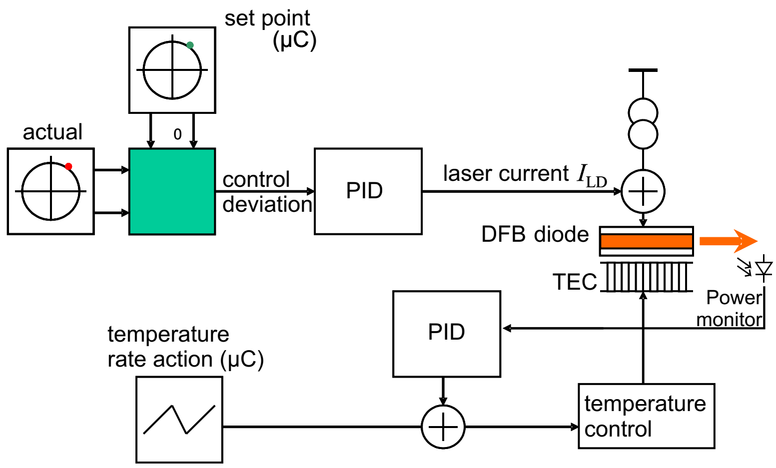


Fig. 6: Power control servo loop

During large scans, the optical power (at fiber output) changes for several reasons. To prevent this, we made a nested servo loop which measures both the optical frequency *and* thoe power and corrects the laser current in a way that the average power remains constant.

Details of the servo loop

The servo consists of a quadrature phase decoder and a pair of nested PID loops.
The angular coordinate of a quadrature signal pair represents the actual laser frequency. A microcontroller generates a second signal pair, representing the target frequency (set point). Thus, the control deviation is encoded as the angle between both signals. The first PID adjusts the laser current in a way that the angle difference reaches zero, thus ensuring the laser frequency approaches its target value.
As a control of the laser current invokes an (often unintended) change of the laser power, we use the substrate temperature of the laser diode as an additional actuator. A second PID controls the temperature in a way that the output power remains constant.



Literature

A. Deninger, Th. Göbel, D. Schönherr, Th. Kinder, A. Roggenbuck, M. Köberle, F. Lison, Th. Müller-Wirts, P. Meissner: Precisely tunable continuous-wave terahertz source with interferometric frequency control
REVIEW OF SCIENTIFIC INSTRUMENTS 79, 044702 (2008)