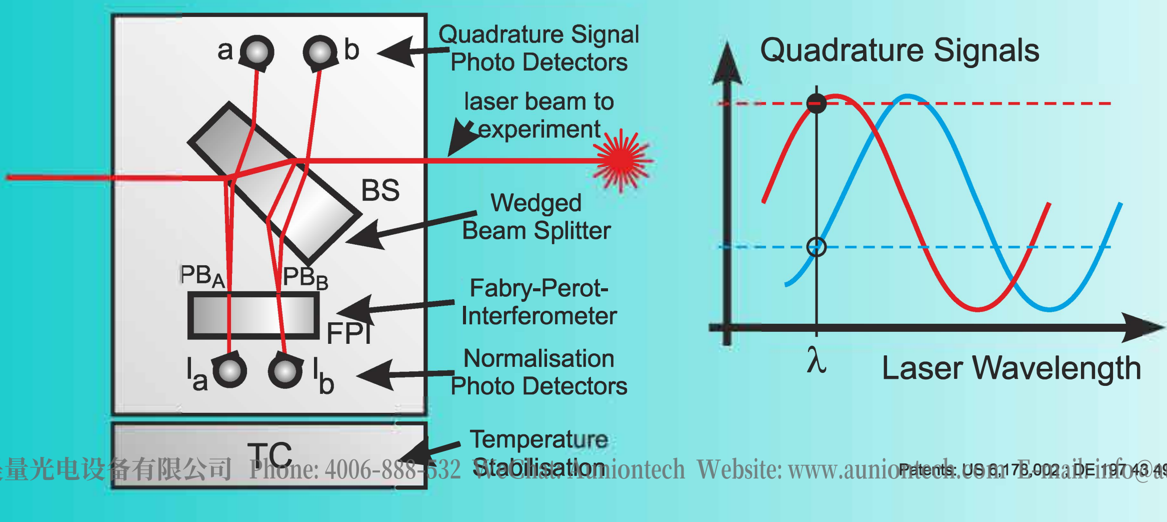
iScan

iScan®

The interferometric frequency control for tunable lasers

The *iScan* is designed for research laboratories as a universal tool for static and dynamic control of the frequency and mode properties of tunable lasers.

- **fast and precise scanning of tunable lasers**
- **stepping to different arbitrary wavelengths**
- **surveillance of the scan behaviour of tunable lasers**
- **Measurement of the wavelength and single-mode stability of tunable lasers**



Patents: US 6,178,002 ; DE 197 43 493 A 1

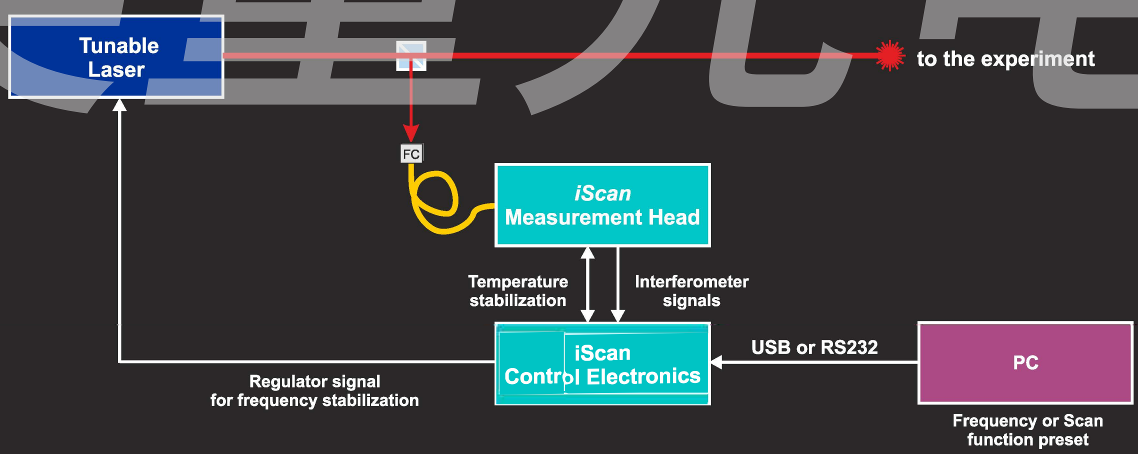
Components of the *iScan* System

The *iScan* system consists of a measurement head and the control electronics.

The *iScan* system is suitable for almost any kind of tunable lasers: diode lasers, DBR and DBF diodes, Ti: Sapphire lasers, dye lasers...

The measurement head contains the interferometer optics, photo detectors, preamplifiers, temperature sensing and control.

The ***iScan Control Electronics*** evaluates the signals of the *iScan* measurement head. It optionally controls the diode laser as well (current, power, temperature). When operated in a closed feedback loop, the control electronics provides a regulator signal to stabilize or tune the laser frequency.



Key Features:

- Laser wavelength stabilization to **arbitrary** values within the tuning range of the laser
- Highly accurate stabilization of the laser frequency **whilst** tuning, thus: elimination of hysteresis, non-linearities, mechanical vibrations and drift
- High measurement speed with simultaneously high resolution (MHz bandwidth)
- Measurement of long-term and short-term wavelength stability without the need to keep the laser frequency constant. (mechanical or thermal drift, jitter, technical bandwidth)
- Comfortable tool for adjustment and optimization of the scanning laser cavity
- Available as stand-alone module or in combination with an ECDL
- Compact design

The *iScan* system employs a patented interferometer setup with four independent photo detectors. The detectors receive several interference signals with a phase difference of approx. 90° (quadrature signals), allowing for monitoring of the tuning behaviour and detection of mode hops.

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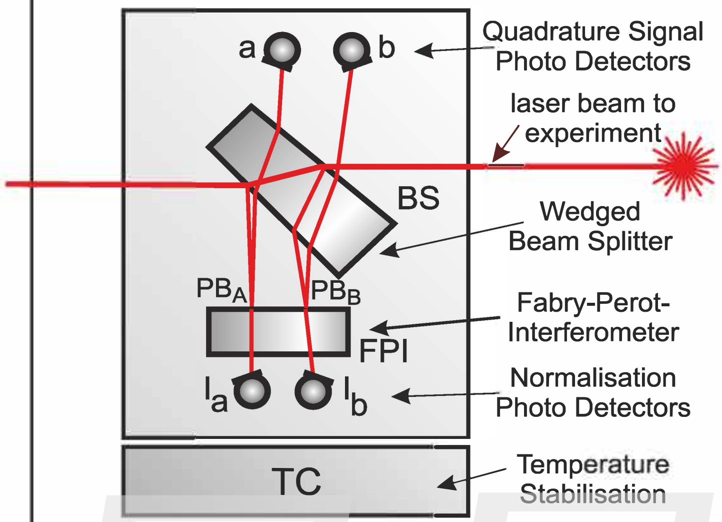
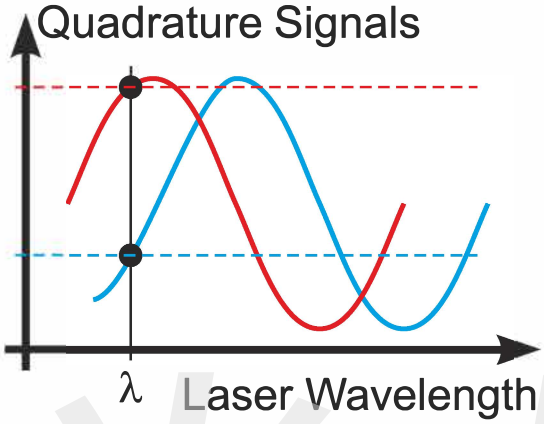
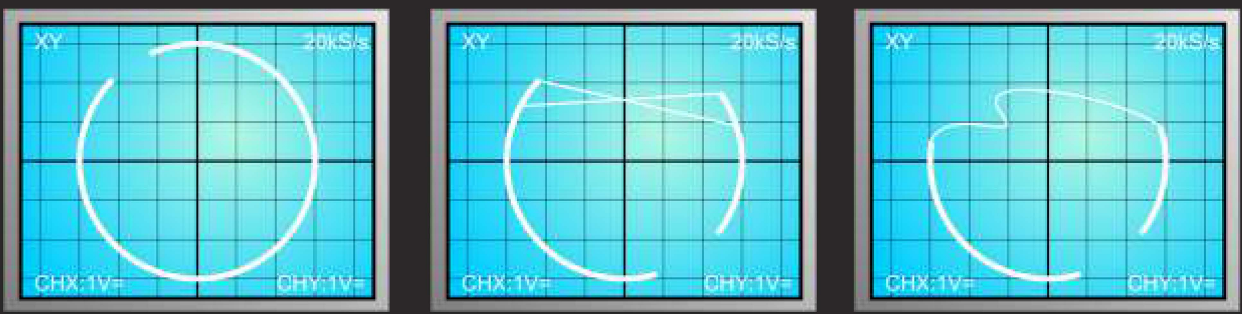




Displaying the quadrature signals on a 2-channel oscilloscope in xy-mode yields characteristic figures (Lissajous figures), which correspond to the properties of the laser.



Single-mode-scan:

The quadrature signals describe a circle with fixed radius.

Mode hop:

Sudden jump across the circle.

Multi-mode-scan:

Circle with a significantly smaller and non-constant radius.

The iScan processes information given in polar coordinates:
The **phase** corresponds to the **wavelength.**
The **radius** corresponds to the **mode purity.**

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Technical Features

Measurement Head:

- Interferometer suitable for 380 to 1100 nm wavelength range (other wavelength on request)
- Different Free Spectral Ranges of 2GHz to 1.5 THz available
- Entire optical setup is thermally stabilized to high precision
- FC-APC Fiber connector for coupling of arbitrary laser sources, or free beam aperture
- OEM versions on request

Control Electronics:

- Digital interfaces: USB and/or RS232
- Arbitrary scans can be realized, including scans for accurate linear frequency tuning of any tunable laser
- Driver and control electronics are integrated either in a desktop or 19"-rack case.

Drivers (optional):

- High voltage amplifiers (single or multi channel)
- Current drivers for galvos
- Laser diode drivers (current and temperature control)

Additional sensors (optional):

- CoSy (compact saturation spectoscopy module) as absolute frequency / wavelength reference
- FPI (Fabry-Pérot cavity)
- FiberEtalon (fiber-based marker etalon for extremely linear scans)

Options:

- Adaptation to tunable solid state lasers such as Alexandrite or Ti:Sapphire lasers, tunable dye lasers and frequency-doubled systems
- Optics and detectors for communication wavelengths
- Stabilization of several lasers relative to each other possible

Literature

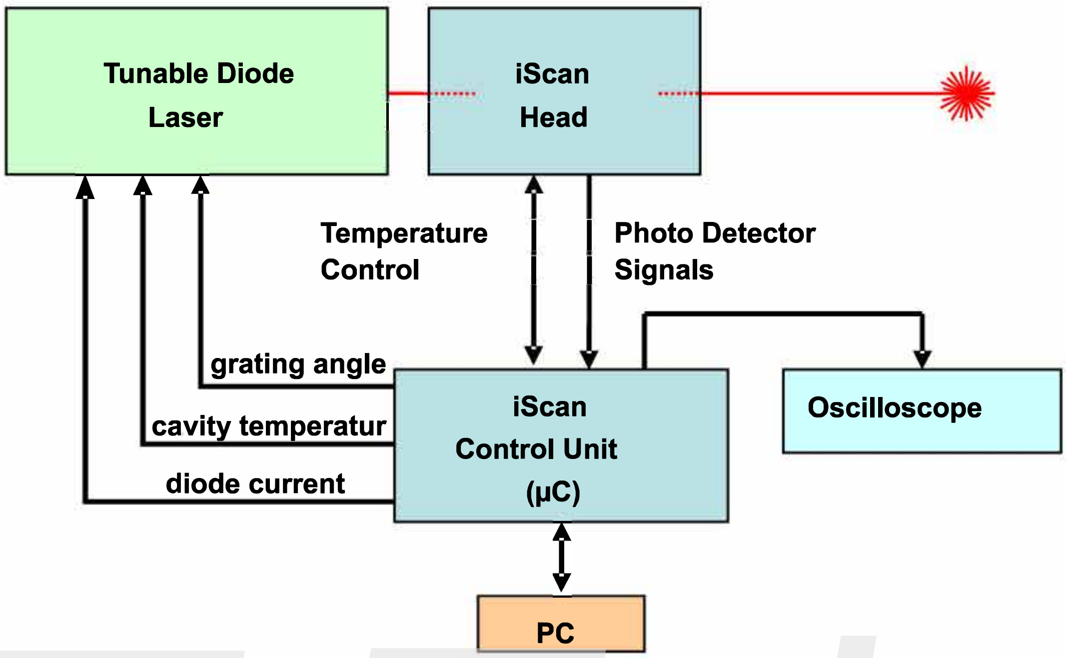
J. Brachmann et al.:Calibrating an interferometric laser frequency stabilization to megahertz precision 10 August 2012 / Vol. 51, No. 23 / APPLIED OPTICS (http://arxiv.org/pdf/1208.2375v1.pdf)

A. Deninger et al.:High-Power Dual-Color Diode Laser System with Precise Frequency Control for CW-THz Generation.OSA, 2007

A. Deninger, et al.:Precisely tunable continuous-wave terahertz source with interferometric frequency control. REVIEW OF SCIENTIFIC INSTRUMENTS 79, 044702 (2008)

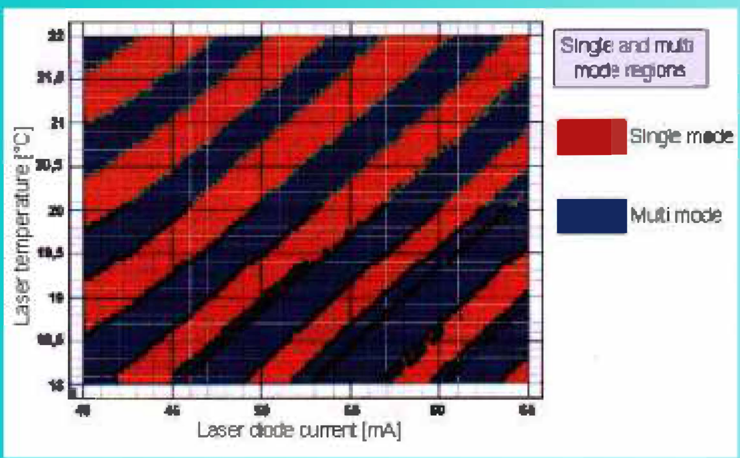
Th. Kinder, Th. et al.:Absolute distance interferometer with grating-stabilized tunable diode laser at 633 nm.Journal of Optics A: Vol 4 No. 6 (2002) p. S364-S368

Acquisition of mode stability charts



In general, tuneable lasers contain a number of electrically driven resonator elements. A mode-hop free frequency scan requires a set of complicated voltage and/or current functions to be applied to these elements. E.g. external cavity diode lasers need the cavity temperature, the injection current and the grating position to be adjusted simultaneously.

As the *iScan* system includes a more-dimensional arbitrary waveform generator and a microprocessor, it can scan through all accessible parameters automatically and find single-mode "corridors" in the parameter space.



Mode chart of a tunable diode laser, recorded with the setup described above.

The plot characterizes laser operation as a function of temperature and injection current of the laser diode. Red stripes indicate areas of stable single mode operation, compared to the blue stripes indicating multi mode operation.

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Application Example II: *cw THz*

Precision Frequency Metrology and Stabilization for Continuous Wave (cw) THz Sources Based on Two-Color Laser Mixing

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 refractive index measurements.

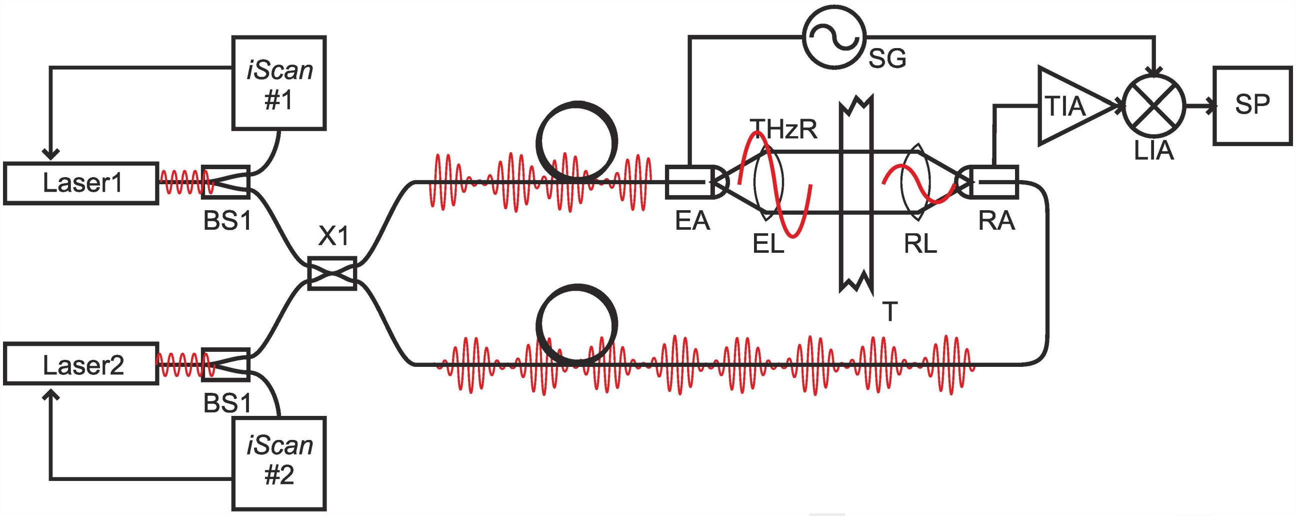
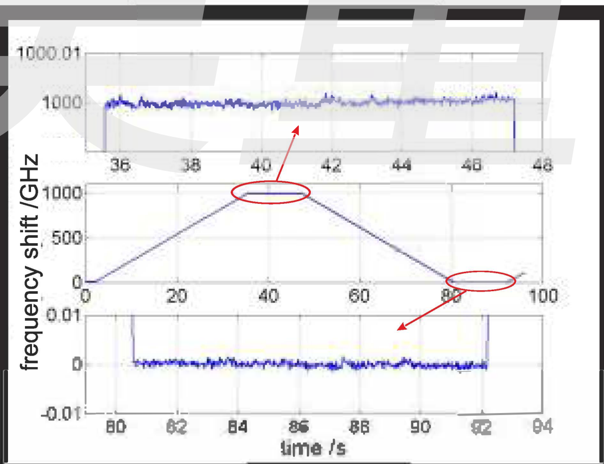
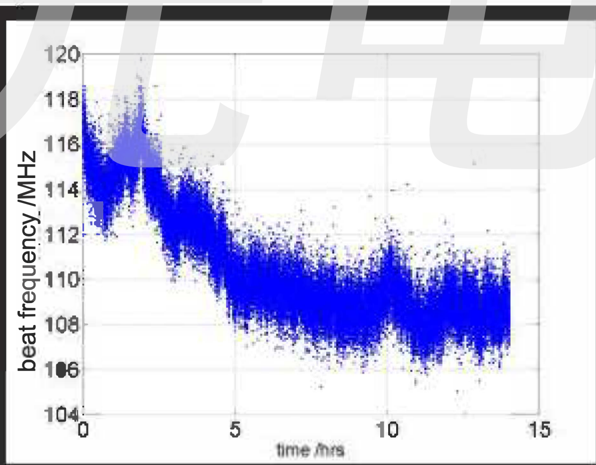


Fig.1: Typical cw THz setup with interferometric frequency control (Laser1/2: Tunable DFB diode lasers; *iScan* 1,2: *iScan* interferometer; BS: Fiber coupler; EA, RA: emitting/receiving antenna; EL/RL: emitter/receiver lens; SG bias signal generator; TIA: transimpedance amplifier; LIA: lock-in amplifier;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



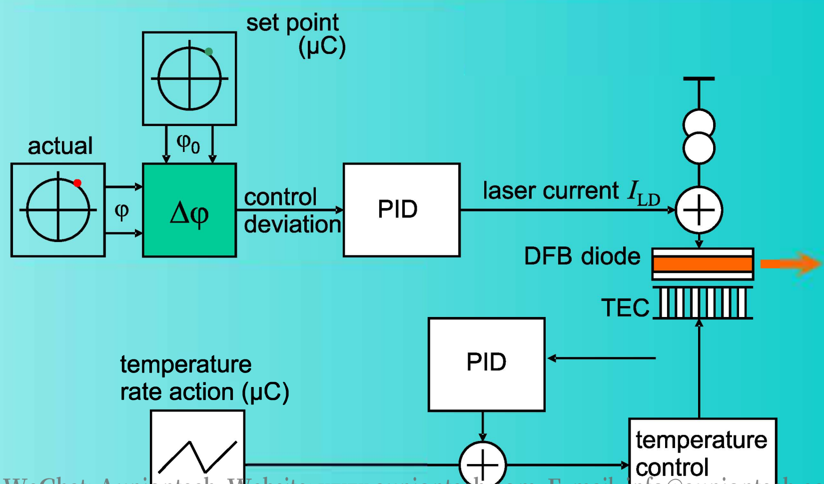
Example 1: Precisely linear 1000GHz scan with some seconds hold at either end



Example 2: Long-term stable optical beat frequency (at 1K change of ambient temperature)

Servo loop for DFB laser diodes

The servo consists of a pair of nested PID loops. The first PID adjusts the laser current such that the laser frequency approaches its target value. In order to prevent changes of the laser power, a second PID controls the temperature in a way that the output power remains constant.

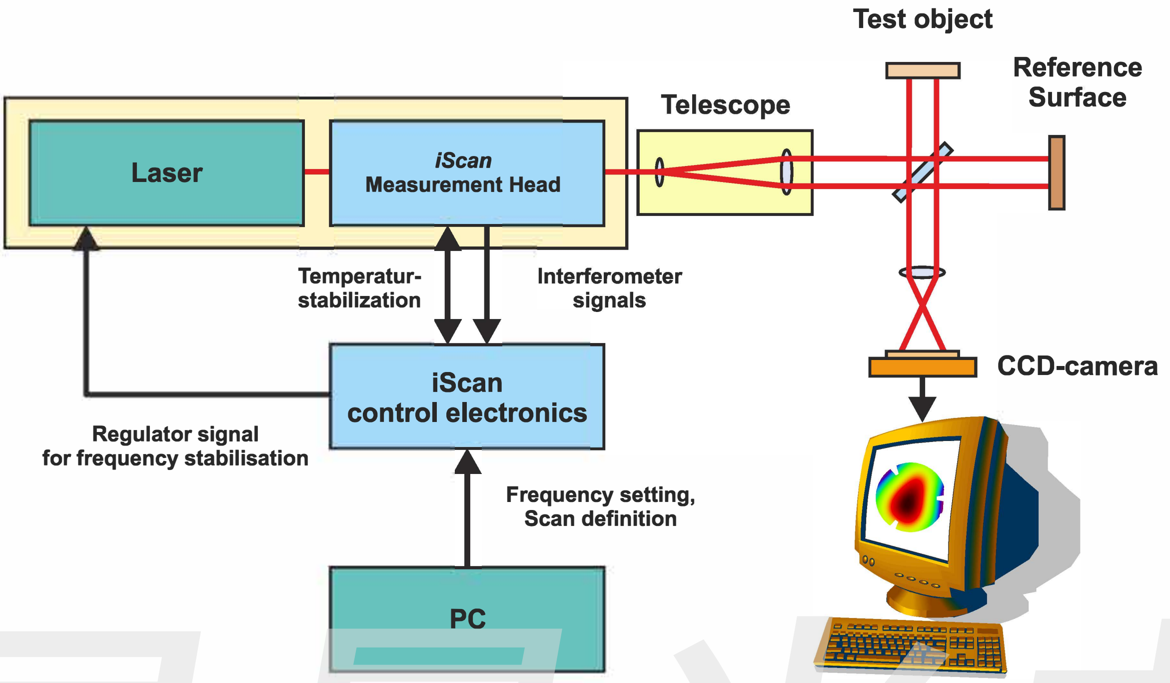


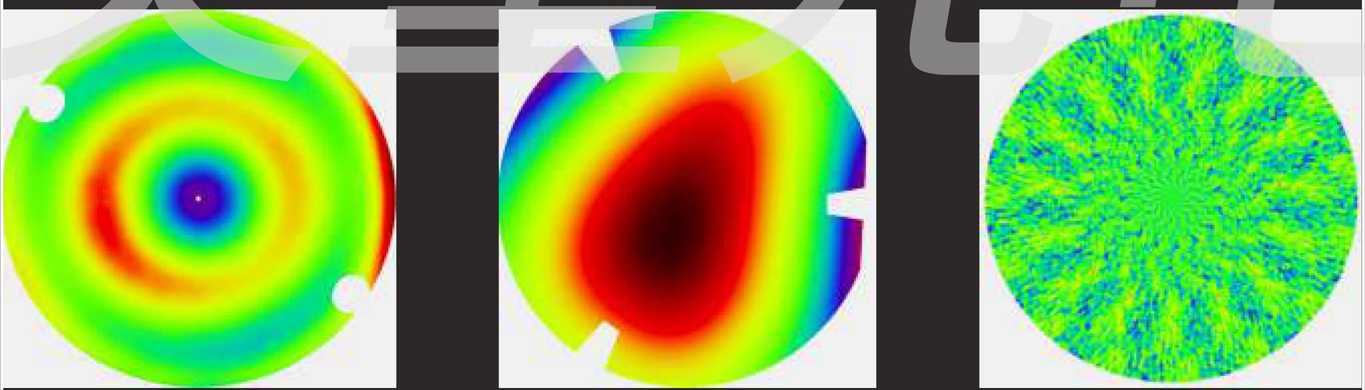
Literature:

Deninger et al.: Precisely tunable continuous-wave terahertz source with interferometric frequency control REVIEW OF SCIENTIFIC INSTRUMENTS 79, 044702 (2008)

Phase Shifting Interferometry

Extremely precise inspection of high quality optics with a Fizeau Interferometer





Conventional phase shifting interferometers need the reference surface to be moved in $\lambda/8$ steps for the phase extraction. This mechanical motion can be replaced by an adequate shift of the laser wavelength. In this case, the *iScan* system guarantees high-accuracy wavelength stepping at arbitrary step width and duration.

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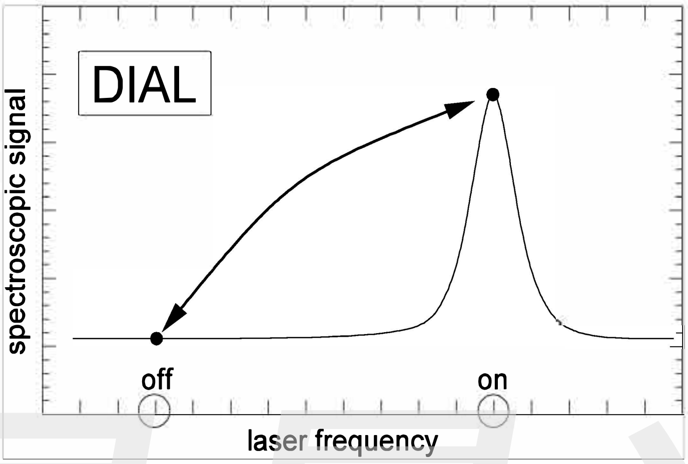
TEM Messtechnik

Application Example IV

LIDAR and spectroscopy

The usage of iScan allows for

- dynamic frequency hopping,
- variable offset stabilization,
- top-of-fringe stabilization and
- side-of-fringe stabilization.



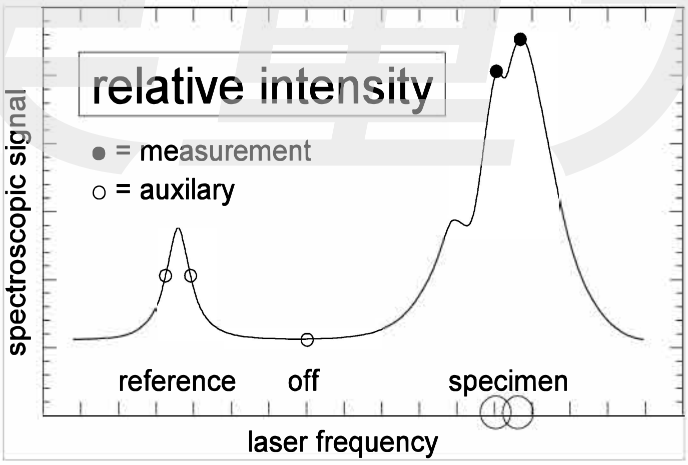
DIAL

Switching amplitude:
arbitrary (limited by the laser)

Switching frequency: ~1 kHz
(limited by laser mechanics)
(small jumps: up to 100 kHz)

Switching accuracy: ~10 MHz

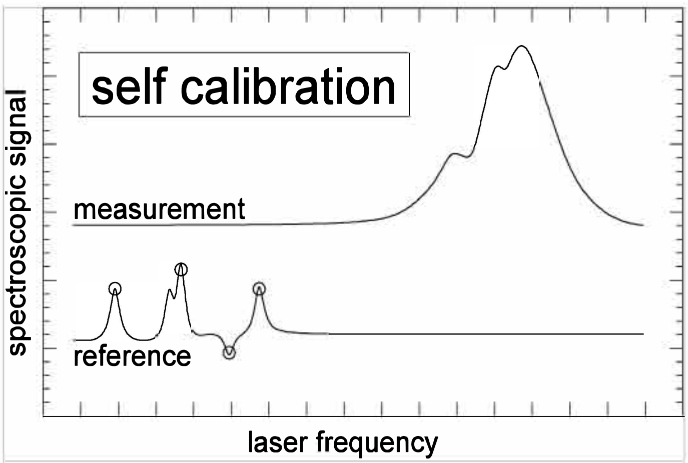
Switching repeatability:~1MHz



Complex Measurements

Use of spectroscopic features to optimize tuning parameters.

Arbitrary number of measurement points.



Spectroscopic reference

Use of a well known atomic transition as reference.

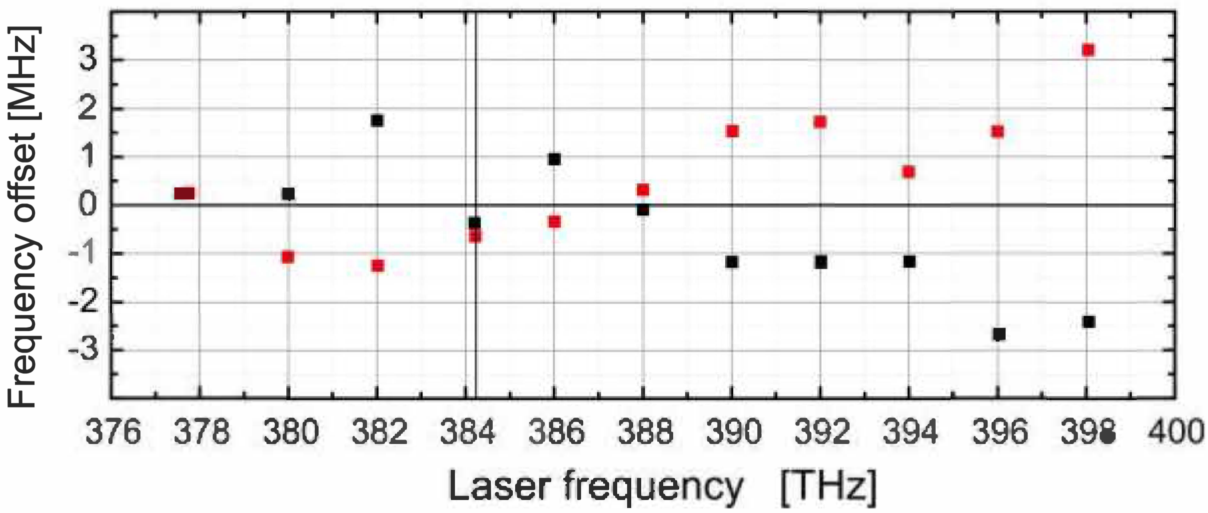
Automatic online recalibration of laser tuning parameters.

Technical data

Interferometer wavelength range:	380 nm to 1100 nm 800nm to 1700nm (IR option) 1200nm to 2700nm (IRext option) (other wavelengths on request)
Power requirements:	minimum 20 … 100 µW (wavelength dependent) maximum 50mW
Free spectral range of interferometer:	2 / 4 / 8 or 100 GHz (others on request)
Beam diameter for free-beam head:	0.7 … 3 mm
Frequency stability:	<<50 MHz for 10 hours < 1 MHz for 10 minutes up to 1 MHz absolute, if locked to atomic reference
Frequency linearity:	<1% of FSR (standard), 0.05% of FSR (with linearization kit)
Frequency scale error:	$<5 \cdot 10^{-4}$ (standard) $<1 \cdot 10^{-6}$ (with dispersion correction kit)
Fiber connector:	FC-APC
Dimensions:	
measurement head	115 mm x 80 mm x 80 mm
control electronics in 19“-rack	483 mm x 343 mm x 150 mm
Interface:	RS232, USB
Electrical supply:	100 … 120 / 200 … 250 V AC, 50 to 60 Hz (switched automatically)

Subject to change without notice. Customer specific solutions on request.

Performance data



Frequency deviation of an iScan stabilized DLpro (Toptica Photonics AG) from an optical frequency comb, measured at MPQ Garching (J. Brachmann et al., APPLIED OPTICS Vol. 51, No. 23 (2012), http://arxiv.org/pdf/1208.2375v1.pdf). iScan included CoSy-Rb (rubidium reference, vertical line) and linearization package. Different colors symbolize measurements on different days in the same lab.

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Development, Manufacturing and Distribution

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03/2013