Technology Offer

Method and Device for Characterizing a Resonator Element

Ref.-No.: 1629-6437-WT

Abstract

This disclosure presents a method and device for precisely measuring the frequency of a scanning diode laser. Applications include LIDAR, gas sensing and spectroscopy of integrated photonic devices like microresonators. The method involves a tunable laser, modulated at two distinct frequencies to generate side band resonances while it is being scanned across a reference cavity (e.g. a fiber loop resonator). This setup enables precise and instantaneous measurement of the optical frequency and tuning speed of a laser with exceptional accuracy. The approach significantly simplifies the system complexity and reduces costs compared to traditional frequency combs and enables spectroscopy with Hz-level precision. The technology promises substantial improvements in high-precision metrology, crucial for applications requiring exact spectral-difference measurements or absolute frequency measurements when used in combination with a reference gas-cell.

Advantages

- **Ultra-High Resolution:** Provides Hertz-level spectral resolution that significantly surpasses conventional systems, enabling the measurement of small spectral features.
- **High Precision with Tunability**: The technology ensures high precision in frequency reference signals through the ability to finely tune the carrier laser frequency over a wide spectral range.
- **Effective Calibration**: Incorporates straightforward calibration methods using standard references like gas cells for both relative and absolute frequency validations.
- **High Power Spectroscopy**: Using a tunable diode laser for spectroscopy enables measurements at much higher optical powers compared to frequency comb techniques.
- **Compact and Modular Design:** The apparatus is designed to be compact and modular, facilitating easy integration into existing systems and scalability depending on application requirements.
- **Cost Efficiency:** It employs readily available, standard optical and electronic components, significantly lowering both initial costs and ongoing expenses compared to traditional frequency combs for example.

Potential applications

- **Resonator Characterization**: Precisely analyzes optical resonators to optimize lasers, filters, and sensors, focusing on properties like free spectral range and resonance linewidth with a precision of down to a few Hertz.
- **Instrument Calibration**: Enhances the accuracy of spectrometers and interferometers through controlled laser frequency and modulation.
- **LIDAR Systems**: Boosts distance measurement accuracy in autonomous vehicles and remote sensing by precisely tuning laser frequencies and measuring shifts between side band resonances.
- **Gas Sensing Systems**: Employs resonator-based optical frequency references for precise gas composition analysis, crucial for environmental and industrial safety monitoring.

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Background

Prior art in optical frequency metrology predominantly relies on optical frequency combs, which, despite their high precision and utility in applications like precision spectroscopy and metrology, face significant limitations. These combs are intricate systems that require octave-spanning spectra and sophisticated servo loops to maintain long-term coherence, making them complex and expensive to implement. They often suffer from low power per comb line and amplitude fluctuations, which can compromise measurement accuracy and application feasibility. Additionally, the technical complexity involved in stabilizing the carrier frequencies of laser radiation pumped into micro resonators for comb generation escalates setup costs and operational challenges, limiting their widespread adoption in industries that require cost-effective and robust high-precision measurement systems.

Technology

This technology (Figure 1) delineates a method and apparatus for the precise characterization of optical resonators, employing a tunable laser light source that is frequency calibrated by a reference cavity. The method involves directing a laser whose carrier frequency is modulated, into a resonator structured with multiple intrinsic resonances, spaced by a defined FSR. Modulation of the laser light's intensity or phase at two distinct frequencies generates side bands, which are symmetrically spaced around the carrier. The process includes continuous measurement of the light's intensity as it is transmitted or reflected by the resonator, while the carrier frequency is finely tuned across a predetermined range. This precise tuning and modulation facilitate the exact calculation of the laser frequency and instantaneous tuning speed. This enables the generation of optical frequency reference signals with applications in high-resolution spectroscopy and for characterizing optical elements in advanced telecommunications systems.

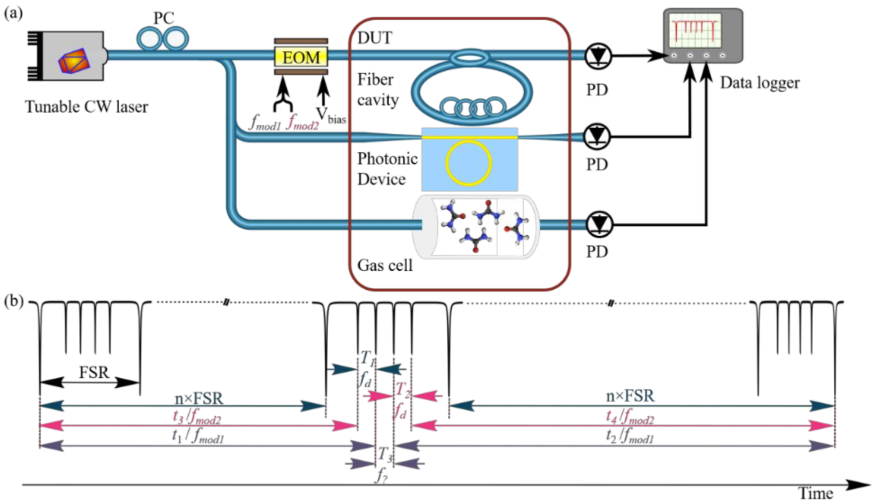

Figure 1: Experimental setup and principles of dual radio frequency (RF) modulation broadband spectroscopy. (a) Measurement scheme. A tunable Continuous wave (CW) laser is modulated by two RF signals (f_{mod1},f_{mod2}) via an electro-optic modulator (EOM), and the modulated light is used to probe the device-under-test (DUT) with quasi-periodic structures with FSR smaller than the modulation frequency, such as fiber cavity or integrated photonic devices. The transmission or reflected light is monitored by a photodiode (PD) and recorded by a data logger. This scheme can also be extended to measure devices with higher FSR or non-periodic structures, such as on-chip small-footprint photonic devices, gas cells. PC: polarization controller. (b) Principle of broadband laser spectroscopy based on dual RF modulation.

Patent Information

Patent filed (WO 2024008730 A1)

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