

## Technical Note – No. 14

### Contributions to the Linewidth of External Cavity Diode Lasers

The linewidth of external cavity diode lasers has several contributions which can be identified by their typical frequency or time scale.

- a) Mechanical vibrations of the cavity: This contribution to the linewidth is on a second timescale and can be compensated by a PID regulator which regulates the piezo voltage. A typical laser linewidth enhancement due to this contribution is in the order of 5-10MHz for our Littrow system and in the order of 2-5MHz for our Littman/Metcalf system at a measuring time of 1s.
- b) Shot noise of the laser current: This contribution to the linewidth is on a millisecond and microsecond timescale. A typical laser linewidth enhancement due to this contribution is in the order of 1MHz for our Littrow system and 200kHz for our Littman/Metcalf system at a measuring time of 1ms.
- c) Spontaneous emission: The contribution of the spontaneous emission is determined by Henry's linewidth formula as published in IEEE JQE 18, 259-264, 1982. Agraval modified Henry's linewidth formula for the presence of an external cavity as published in IEEE JQE-20 468-471, 1984. A typical time scale of this contribution is in the order of nanoseconds. The natural linewidth strongly depends on the coupling of the laser chip to the external cavity and may reach values below 100kHz in case of perfect coupling.
- d) Coupled cavity contributions: Agraval's analysis determines the linewidth of an external cavity diode laser depending on detuning between the external cavity frequency relative to the mode of the diode laser chip. The lower the value of the detuning of the frequency is, the lower is the value for the linewidth of the laser system. The linewidth varies from below 100kHz up to several GHz by detuning the external cavity frequency relative to the mode of the diode laser chip. These contributions are on a time scale of typically several 100 MHz up to several GHz. The lower the reflectivity of the laser facet is, the lower is the influence of the detuning effect on the linewidth. For a diode laser facet reflectivity in the order of a 1%, the low linewidth operation regime does have a width of only a few picometer. For a diode laser with reflectivity values in the order of 0.001%, the linewidth varies between several 10th of kHz and 100kHz as published by Zorabedian, IEEE JLT 10, 330-334, 1992.

Between the contributions a) and b) can be easily distinguished with a simple heterodyne experiment as shown on the second page of this technical documentation. The strength of contribution d) strongly depends on the quality of the antireflection coating of the diode laser.

Document: <http://data.sacher-laser.com/techdocs/linewidth.pdf>

Sacher Lasertechnik GmbH  
Hannah Arendt Str. 3-7  
D-35037 Marburg, Germany

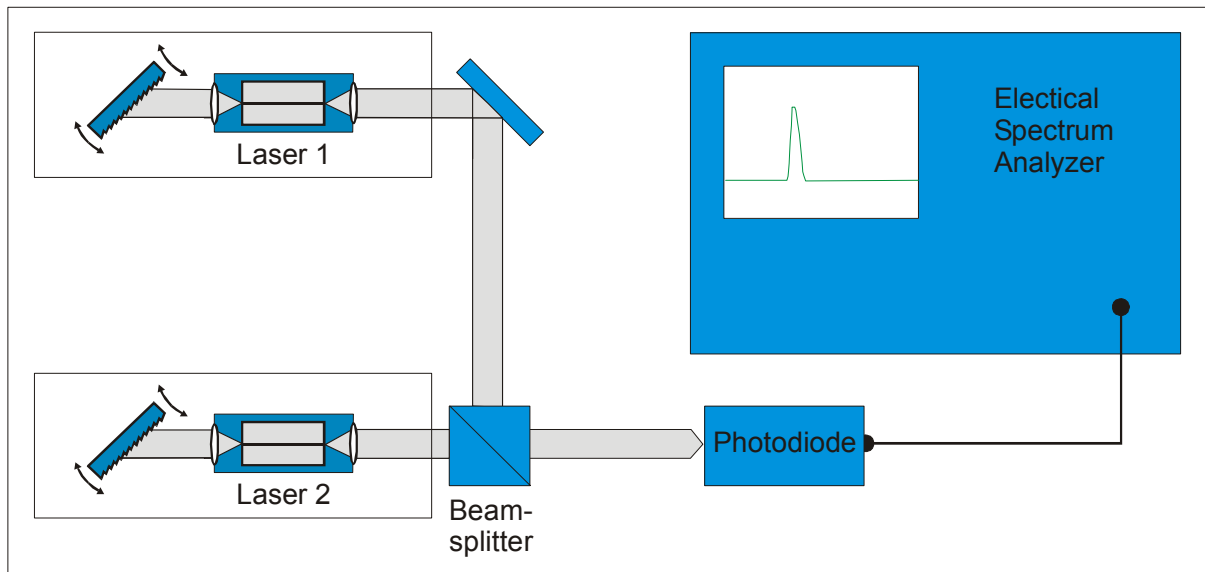
Tel.: +49 6421 305290  
Fax: +49 6421 305299  
Email: [contact@sacher.de](mailto:contact@sacher.de)

Sacher Lasertechnik, LLC  
5765 Equador Way  
Buena Park, CA 90620, USA

Tel.: 1-714-670-7605  
Fax: 1-714-670-7662  
Email: [sales@sacher-laser.com](mailto:sales@sacher-laser.com)



## Method of detection of the linewidth of External Cavity Diode Lasers



The figure shows an experimental setup for measuring the linewidth of external cavity diode lasers. The laser beam of Laser 1 and Laser 2 are adjusted collinear and coupled into a photodiode. The emission wavelength of Laser 1 and Laser 2 are slight detuned against each other. A typical value of the detuning is in the order of 50MHz to 2GHz. The photodiode shows an heterodyne beat signal with a detuning frequency which is analyzed via an electrical spectral analyzer. The linewidth of the diode lasers can be estimated by the FWHM of the heterodyne signal. Depending on the sweep frequency of the electrical spectrum analyzer, it is possible to distinguish between the contributions of the mechanical vibrations of the cavity and of the shot noise of the laser current to linewidth of the lasers.

### Ultra-short time sweep (1 $\mu$ s sweep time or below):

During a ultra-fast sweep of the electrical spectrum analyzer, the contributions below 1MHz of the shot noise of the laser controller and the mechanical vibrations of the external cavity are quasi-static. With each sweep, the absolute position of the peak is found at a slightly different position. The FWHM width of the heterodyne signal summarizes the high frequency contributions of the shot noise of the laser current driver and of the spontaneous emission noise of the laser.

### Short time sweep (1ms sweep time or below):

During a fast sweep of the electrical spectrum analyzer, the contributions of the mechanical vibrations of the external cavity are quasi-static. With each sweep, the absolute position of the peak is found at a slightly different position. The FWHM width of the heterodyne signal summarizes the contributions of the shot noise of the laser current driver and of the spontaneous emission of the laser.

### Long time sweep (1s sweep time or longer):

With this sweep time of the electrical spectrum analyzer, the slow changes of the wavelength due to the mechanical vibrations of the external cavity are summarized up. Therefore, this value is a measure for the mechanical stability of the external laser cavity.

Document: <http://data.sacher-laser.com/techdocs/linewidth.pdf>

Sacher Lasertechnik GmbH  
Hannah Arendt Str. 3-7  
D-35037 Marburg, Germany

Tel.: +49 6421 305290  
Fax: +49 6421 305299  
Email: [contact@sacher.de](mailto:contact@sacher.de)

Sacher Lasertechnik, LLC  
5765 Equador Way  
Buena Park, CA 90620, USA

Tel.: 1-714-670-7605  
Fax: 1-714-670-7662  
Email: [sales@sacher-laser.com](mailto:sales@sacher-laser.com)

