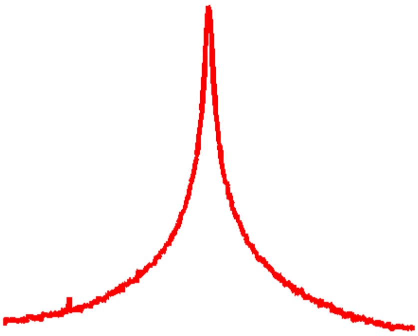
Spectral Linewidth of Distributed Feedback Laser



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1 Introduction

This application note deals with the way we measure and analyze the linewidth of Distributed Feedback Lasers (DFBs). The linewidth of the diode stems mainly from intrinsic optical phase and frequency fluctuations caused by spontaneous emission. However, the measured linewidth depends strongly on the current noise and the quality of the measurement setup, both of which differ from lab to lab. This application note is motivated by the fact that there are different methods to measure linewidth and several ways to interpret it, often leading to varying results. By describing our approach we hope to make clear how we determine linewidth.

Since the determination of linewidth is relatively sophisticated and time consuming, we carry out this measurement only randomlyon sample DFBs. If you would like the linewidth of your DFB to be measured before shipment, please let us know ahead of time.

2 Measurement and analysis

Our interpretation of linewidth is based on three functions that are described in chapter 2.1. In chapter 2.2 we provide you with our measurement setup. In chapters 2.3 and 2.4 a particular measurement and its analysis is described.

2.1 Theoretical background

For the interpretation of the measurement three functions, Gauss, Lorentz and Voigt, are available. The width of the Lorentz profile expresses the natural linewidth of the DFB that theoretically can be reached using an ideal current source without any noise and under absolutely stable environmental conditions. Generally, the information of the Lorentz part is located in the sides of the beat note signal (see chapters 2.3 and 2.4). This is due to the fact that the technical noise falls with $1/f$ (called pink or $1/f$ noise) with increasing distance from the beat note. Natural linewidth is caused by white noise that appears at all frequencies similarly.

The width of the Gauss profile serves as a benchmark for the assessment of the statistical fluctuations that stem from the noise of the current source and fluctuations of temperature and pressure in the lab.

Finally, the Voigt profile connects the Gauss with the Lorentz profile and thus reflects the actual linewidth when running the DFB under particular environmental conditions, using a particular driver. Consequently, since the Gaussian part of the Voigt profile is lab-dependent (while the natural linewidth remains the same), different linewidth values can be obtained in different labs. The following table gives an overview of the three fit profiles.

Profile	**Characterization**
Gauss	Covers fluctuations in the current and in environmental conditions, e.g. fluctuations in temperature or pressure.
Lorentz	Describes the natural linewidth of the laser.
Voigt	Convolution of a Lorentz profile and a Gaussian profile. Reflects the actual linewidth.

Table 1: Fit profiles and their characterization

2.2 Setup

To determine linewidth we use the self-delayed heterodyne measurement technique. This technique is based on the conversion of optical phase and frequency fluctuations caused by spontaneous emission into variations of optical intensity.

As shown in Figure 1, the collimated DFB beam passes an optical isolator (OI) and is then divided into two beams by a beam splitter. Beam 1 is coupled into a delay fiber, while beam 2 passes through an AOM (acousto-optic modulator). Both beams are brought together using a beam splitter cube and detected with a fast photodiode that transforms the fluctuations in optical intensity into photo current variations. The DC signal of the photo current is filtered out, while the AC signal is amplified and guided to an electrical spectrum analyzer (ESA).

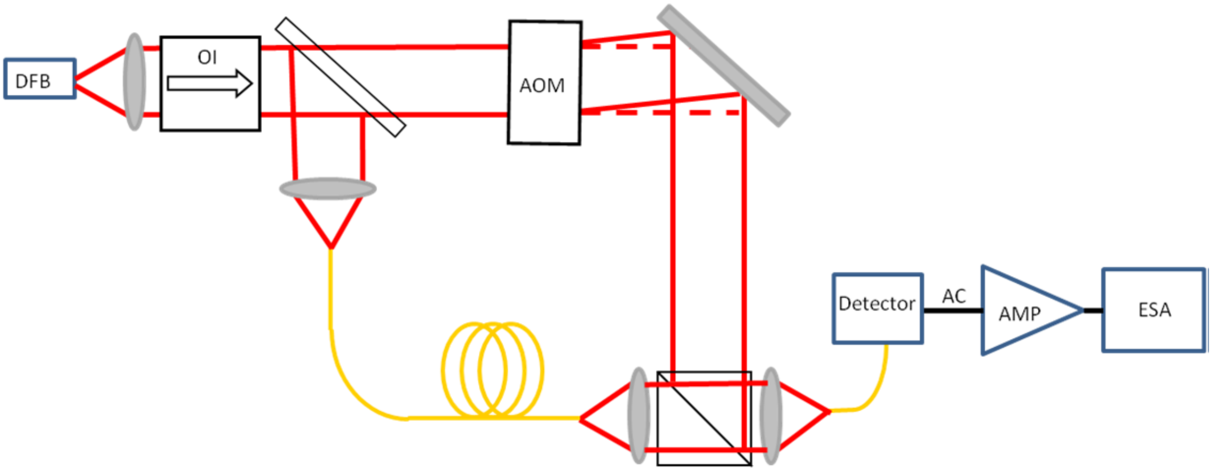

Figure 1: Setup of a LIN - measurement

For an accurate determination of the linewidth it is crucial to get the two beams uncorrelated. This is accomplished by choosing a fiber with a length greater than the coherence length of the DFB. The frequency of the first order diffraction beam after the AOM is shifted by 110 MHz, while the zero order beam is blocked.

2.3 Measurement

Figure 2 shows the logarithmic view of the linewidth measurement with a 60 MHz span and Figure 3 shows a measurement with a span of 1 MHz. Both spectra were acquired at a sweep time of 50 ms and a resolution bandwidth of 30 kHz at a current of 160 mA. For better visibility 50 sweeps were averaged. The power spectral density is normalized and the frequency is shifted from the 110 MHz beat note to 0 Hz.

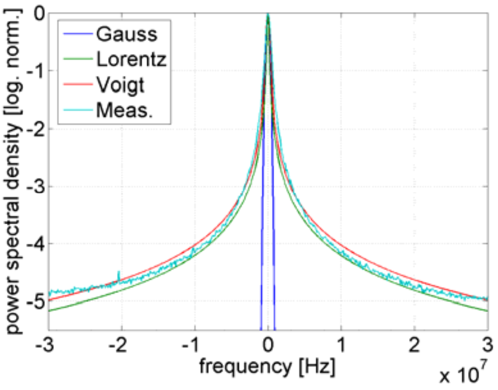

Figure 2: Logarithmic view with a span of 60 MHz, sweep time: 50 ms, resolution bandwidth: 30 kHz, trace mode: Average Sweep Count 50.

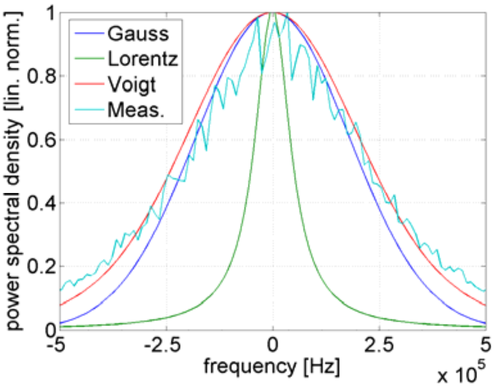

Figure 3: Linear view with a span of 1 Mhz.

2.4 Analysis

The fit parameters were chosen with the intent of fitting the measurement with the Voigt profile at the sides of the beat note signal as shown in Figure 2 and in the area of the beat note as depicted in Figure 3.

As seen in Figure 2 the Lorentz function fits the measurement in the sides of the curve, while it does not carry any information about the technical noise that is located near the beat note signal, as depicted in Figure 3. Correspondingly, as seen in Figure 2, the Gauss function does not carry any information about the natural linewidth and represents only the technical noise near the beat note signal. Table 2 shows the measurement and fitting results for this particular DFB.

Profile	Full Width Half Max [kHz]
Measurement	470
Gauss	425
Lorentz	100
Voigt	481

Table 2: Measurement and analysis results.

Due to the principle of the heterodyne measurement method, the obtained values for the FWHM (Full Width Half Max) are twice as big as the actual widths. In our data sheet we specify only the technical value that is obtained from the FWHM of the measured curve divided by two:

$$\delta\nu_{tech} = \frac{FWHM}{2}\ .$$

2.5 Collaboration with the Ferdinand-Braun-Institute

Our linewidth measurement setup was developed with the help of our partner, the Ferdinand-Braun-Institute. Special thanks go to the people of the laser metrology group (http://www.physik.hu-berlin.de/qom/standardseite-en) who supported us with comparative measurements and their experience in the analysis. In the papers cited below, two different methods of linewidth measurment are described, of which one is based on the self-delayed heterodyne method that we use.

High-power distributed Bragg reflector ridge-waveguide diode laser with very small spectral linewidth. (K. Paschke, S. Spießberger, C. Kaspari, D. Feise, C. Fiebig, G. Blume, H. Wenzel, A. Wicht, and G. Erbert, Optics Letters, Vol. 35, Issue 3, pp. 402-404 (2010)).

Narrow Linewidth DFB Lasers Emitting Near a Wavelength of 1064 nm. (S. Spießberger, M. Schiemangk, A. Wicht, H. Wenzel, O. Brox, and G. Erbert,
J. Lightwave Technol., vol. 28, no. 17, pp. 2611-2616 (2010).

3 Abbreviations

DFB	distributed feedback laser
AOM	acousto-optic modulator
ESA	electrical spectrum analyzer
OSA	optical spectrum analyzer