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Narrow Linewidth Lasers for Brillouin Light Scattering Spectroscopy

Nonlinear spectroscopy technologies have proven their potential as powerful tools in material sciences. Raman spectroscopy is today without a doubt among one of the most standard material characterization methods for analysis of crystalline materials. As magnetic materials gain increased importance for information technology, the characterization of spin waves is moving into the focus of scientists. In this case, the magnetic properties of such materials are especially of interest and Brillouin light scattering spectroscopy (BLS) is then the perfect technique to investigate with.

Background

Nonlinear optical effects are exploited in a wide range of technologies. In particular, two common nonlinear optical scattering methods, Raman and Brillouin scattering, both give important insight into the physical properties of the material under investigation. While Raman spectroscopy reveals the structure or chemical composition, Brillouin spectroscopy provides information on a larger scale such as the elastic or magnetic properties. Although the physical processes of both can be compared up to a certain degree, the big difference is that the Brillouin signal is in the GHz region and the Raman signal is in the THz region or relative to the incident laser light. This puts even higher demands on the spectral purity and linewidth of the incident laser light in order to reveal the very weak Brillouin signal, when compared with Raman spectroscopy.

In this application note, we discuss the laser characteristics needed for Brillouin spectroscopy and show that this technique can be used to characterize the magnetic properties of ferro-magnetic thin films. These are used in spintronics and magnonics, new approaches to use magnetic effects in computing for several limitations of the current CMOS (Complementary Metal Oxide Semiconductor) architecture [1]. Both fields of research promise to play important roles in future generations of computer devices.

Characterization of laser sources

The term Brillouin light scattering refers to the nonlinear optical creation of an acoustic phonon or a magnon [2]. The resulting photon-phonon/magnon interaction results in a very weak Brillouin signal typically in the low frequency GHz region in relation to the incident laser light. In order to expose the resulting weak Brillouin signal, the laser line must have typically better than 20 dB side mode suppression, and in some cases as good as

100 dB. In addition, the linewidth of the laser must be very narrow to distinguish the Brillouin signal from the incident laser line.

For the measurement in this application note, a fixed wavelength, single frequency (10 MHz) diode pumped laser with spectral purity 20 dB and 100 mW output power was used (Cobalt Crisp 450 nm). The linewidth and power level is well suited for spectroscopy of magnetic or metallic foams such as permalloy.

In contrast to the fixed wavelength laser above, a tunable source of red laser light was also used to investigate how the Brillouin signal varied with wavelength. The tunable laser light source (Cobalt) is based on Optical Parametric Oscillator (OPO) technology [3]. The output has a broad tunable range between 670 nm and 730 nm providing up to 100 mW power levels and operates single frequency (10 MHz) with exceptional spectral purity (100 dB).

Due to the very weak low frequency Brillouin signal an especially sensitive high resolution Tandom Fabry-Pérot interferometer is typically used (see [3] for details). By placing a mirror in the sample position and using adequate ND filters to suppress the laser line, such an interferometer can be used to analyze the emission spectrum of all lasers. Figure 1 shows the spectrum of the tunable laser light source, C-WAVE. The strong laser line is shown in GHz and the size of the peak is in order of magnitude higher than the side modes. The data show that the side modes are suppressed to the order of 100 dB. By the fixed wavelength diode pumped Cobalt Crisp 450 nm has a side mode suppression of approx. 20 dB, both laser sources are well suitable for BLS spectroscopy, as can be seen in the following example.

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