GÖTEBORGS UNIVERSITET

Frequency comb Brillouin microscopy

FELIPE ADEMIR ALEMAN HERNANDEZ
Institutionen för fysik
Naturvetenskapliga fakulteten

Akademisk avhandling för filosofie doktorsexamen i fysik, som med tillstånd från Naturvetenskapliga fakulteten kommer att offentligt försvaras fredagen den 19:e november 2021 kl. 10.00 i PJ salen, Institutionen för fysik, Kemivägen 9, Göteborg.

ISBN: 978-91-8009-538-9 (PRINT)
ISBN: 978-91-8009-539-6 (PDF)

GÖTEBORGS UNIVERSITET

Abstract

Brillouin light scattering (BLS), an almost a century old technique, has evolved into a powerful and versatile method to study acoustic and magnetic phenomena down to the nanometer size scale. Presently, BLS can be applied in fields as diverse as acoustics, spintronics, geosciences and biophysics. In addition, the advent of ultrafast laser sources has seeded interests in studies of light-matter interactions under extreme conditions.

Despite the capabilities and unique information that BLS can provide, it suffers from highly demanding and complex instrumentation. Brillouin spectrometers tend to be large, expensive and highly sensitive devices. This has delayed the progress of ultrafast applications of BLS compared to other successful coherent spectroscopic techniques.

This thesis aims to contribute to this nascent field by introducing a new concept named frequency comb Brillouin microscopy. This method exploits the highly structured properties of a GHz repetition rate frequency comb as a pump to selectively enhance the Brillouin scattering intensity, while retaining the inherent high spectral resolution of BLS. Furthermore, due to the impulsive character of the frequency comb, ultrafast generated quasi-particles can be observed. Applications of this technique include the direct observation in frequency domain of ultrafast demagnetization dynamics, ultrafast formation of phononic combs, Brillouin imaging of phonon and spinwave caustics, excitation of quantized perpendicular spinwave modes and selective scattering enhancement of Brillouin modes, to mention a few presented in this thesis.

In a pursuit to overcome the instrumental complexity of BLS spectrometers, and to develop a merchantable instrument which can be used for spintronics research, this thesis also explores alternative Brillouin instrumentation methods. For this purpose, first a virtual-image phase array spectrometer was evaluated for studies of thin magnetic films. Secondly, an apparatus based on the magneto-optical Kerr effect and very high speed electronics was devised and tested in spintronic devices. Implementations here include contact-less ferromagnetic resonance (FMR) spectroscopy of spin-Hall nanooscillators (SHNOs), phase-resolved imaging and fast acquisition of synchronization maps in SHNO networks for future oscillator-based computing schemes.

Keywords: *Brillouin light scattering, Fabry-Perot interferometer, spinwave, acoustic phonon, virtual-image phase-array, frequency comb, Frequency-resolved magnetooptical Kerr effect, spin-Hall nano-oscillator, ferromagnetic resonance, microscopy.*