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Title of the doctoral dissertation: **Widely-Tunable All-Fiber Laser Source for Coherent Raman Scattering Microscopy**

Abstract

The development of fiber laser sources has been a focus of research for several decades, driven by the increasing demand for numerous applications, including Coherent Raman Scattering (CRS) microscopy. The CRS stands out among microscopy techniques due to its advantages of label-free imaging and high resolution. This thesis will introduce three wavelength tunable laser sources that exploit nonlinear effects in optical fibers to enable Raman measurement in both fingerprint and C-H stretch spectral regions. Access to the fingerprint region is particularly valuable, as it facilitates improved chemosensitivity assessment, an area that remains poorly addressed by current state-of-the-art fiber light sources.

The first dual-wavelength Stimulated Raman Scattering (SRS) light source to be developed will allow measurements in the fingerprint Raman region, covering the range from 950 cm^{-1} to 1600 cm^{-1}. This fiber laser source will deliver tunable output for the pump and Stokes beams ranging from 913 nm to 930 nm, and from 1020 nm to 1070 nm, respectively, with an average power of 40 mW for each beam. The tunability of the Stokes beam will be achieved by using a novel method of spectral broadening through Self-Phase Modulation (SPM) of chirped pulses in all-fiber configuration. The light source will be validated through its implementation into SRS microscopy for imaging polystyrene beads and leukemic cells.

The second light source will be designed to perform imaging in both the fingerprint and C-H stretch Raman regions. The fiber optical parametric oscillator using the Degenerate-Four-Wave Mixing (D-FWM) will be presented. The system will be built around the fiber oscillator with a fixed central wavelength, serving as a seed beam. The pump tunability will be achieved exploiting a novel method involving spectral broadening of chirped pulses, followed by spectral filtering and amplification similar to the approach used in the first light source. The obtained D-FWM signals will be tunable between 730 nm to 940 nm. While considering the second beam at 1030 nm, this can enable Raman measurements in the range from 929 cm^{-1} to 3990 cm^{-1}.

The third part of the thesis will focus on development of a novel method for tuning D-FWM sidebands based on the SPM of chirped pulses. This method will involve varying the

chirp of the pump pulses at fixed central wavelength that are next injected into the concatenation of standard fiber and a photonic crystal fiber. The outermost redshifted SPM peak exhibits significant spectral power density to act as a tunable pump for the D-FWM process. When combined with a 1030 nm beam, this may allow measurements in the fingerprint and C-H stretch Raman regions spanning from 873 cm^{-1} and 3738 cm^{-1}. Coherent Anti-Stokes Raman Scattering imaging of polystyrene beads and droplet paraffin will also be conducted to validate this light source.