Photonic crystal fiber infiltrated with high-nonlinear liquids for supercontinuum generation in mid-infrared

Supercontinuum light is generated when a collection of nonlinear optical processes and effects of dispersion act together upon the input pulses, which propagate in an optical fiber, to cause spectral broadening of the pulse. As a result, the output beam has a broad spectral bandwidth. The optical fiber-based supercontinuum source has played a significant role in various applications ranging from communication to advanced optical coherence tomography.

In general, fibers made from glass are used for supercontinuum generation (SG). However, some glasses, e.g., silica, are not transparent in the mid-IR and has relatively small nonlinearity. Thus, SG in silica fiber is limited to the visible and the near-IR range. On the other hands, fibers made from soft-glasses, e.g, telluride, chalcogenide, have high attenuation, poor mechanical stability, and cannot be fusion spliced with typical silica fibers. The chalcogenide fibers typically require the use of complex pump laser systems for SG because of their specific dispersion profiles.

In this project, we are going to use a silica hollow-core photonic crystal fiber (PCF) infiltrated with a nonlinear liquid into the core as the nonlinear propagation medium, which is named *liquid-core PCF*, for SG application, as shown in figure 1. The liquid-core PCF has unique advantages:

(i) Some liquids, such as organic solvents and oils, have high nonlinear refractive indices and high optical transparency in the near-infrared (near-IR) and mid-IR. Especially, the oils have extremely high nonlinear refractive index under irradiation of long-pulse laser. The high nonlinearity of liquids allows to obtain broad mid-IR SG with short propagation length of the fiber and low peak power of input pulse.

(ii) The PCF has a high degree of freedom to optimize its dispersion, which is a key factor to determine SG, by changing the size of air-holes in the cladding region, lattice pitch, core diameter.

Therefore, due to the high nonlinearity and transparency of liquid, the design flexibility of the PCF, liquid-core PCF has a high potential for broad SG in mid-IR range with the standard, commercial laser as a pump source.

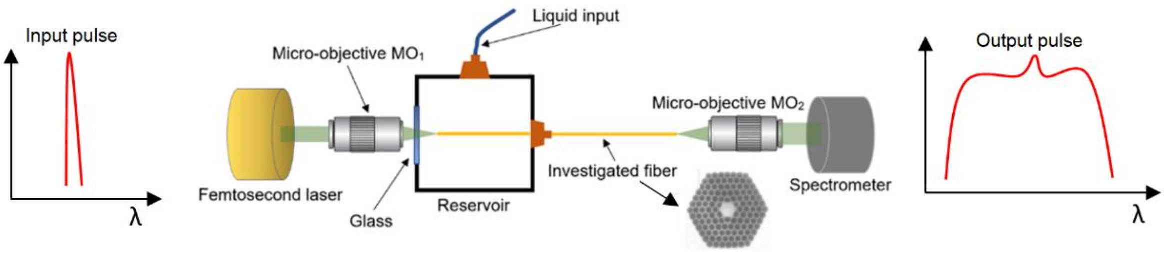

Figure 1. The schematic of the system to measure SG in liquid core PCF.

Both numerical and experimental research will be carried out within the project. Based on the simulation, the optimal geometry of the PCF fiber will be determined. The simulations will include the calculating of the dispersion of liquid-core PCF with various geometrical parameters to identify the fiber, which has flat, low dispersion and zero-dispersion wavelength matched to selected commercial high peak-power laser source. Numerical modelling will also be used to analyze non-linear phenomena in the fiber which results in SC generation.

As part of the experimental work, the linear and non-linear properties of various oils will be analyzed. The optimized fiber will also be fabricated. Its parameters will be measured experimentally, such as its dispersion, attenuation. Once filled with oils, using femtosecond lasers and nanosecond pulse lasers will be used for SG in the fiber. Experimentally determined SG will be conducted to measure the spectral bandwidth and normalized intensity of the output beam in near and mid-IR range.

Temperature influence on the dispersion and SG of the liquid-core PCF will be numerical analysis and experimentally verify. With the high-temperature sensitivity of the liquids, the liquid-core PCF has a capability for real-time dispersion tuning, and thus characters of SG via changing ambient temperature.