

CARS endoscopy using hollow core fibers

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Coherent anti-Stokes Raman (CARS) endoscopy developments have been hampered by the large four wave mixing (FWM) signal arising in solid core silica fibers that is order of magnitudes stronger than the CARS signal coming from the sample itself. Earlier there had been attempts to circumvent this problem using hollow core band gap fibers, though these fibers showed a limited transmission window [1]. Within this work, we present a nonlinear endoscope suitable for CARS, 2photon and SHG imaging using a single hollow core fiber that (1) delivers ultra-short pulses at the sample plane and (2) collects the back emitted/reflected signals. Our endoscope employs a Kagome hollow-core fiber [2] featuring a double silica cladding for signal back collection (Fig 1. a). The single guided mode propagating into the hollow core (Fig. 1 b) shows an attenuation of few dB/m over a broad transmission window extending from 700nm to 1100nm (Fig. 1 c). The low dispersion found in Kagome fiber, 5ps/nm/km, makes it ideal for short pulse propagation as a 100fs pulse is virtually unaffected after a propagation of a several meters within this type of fiber. Most importantly, the fiber core nonlinearity equals the one found in air and no FWM signal is measured when two overlapping 100fs pulses propagate through the fiber core.

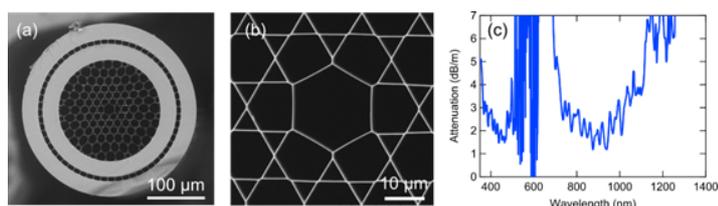


Fig. 1 SEM micrograph of the developed Kagome lattice double clad fiber (a), zoom on the hollow-core region (b) and attenuation spectrum (c).

Using this fiber, we have developed a scanning type fiber endoscope based on resonant piezo scanner; similar to the one reported in [3], able to image a 300μm field of view at a speed of 1 frame/s. The endoscope distal tip houses the piezo scanner and a distal lens exhibiting a diameter of 2.1mm in total. Figure 2 presents a few CARS/SHG images taken with the built endoscope on different tissues samples (CH-vibration bonds at 2850cm⁻¹):

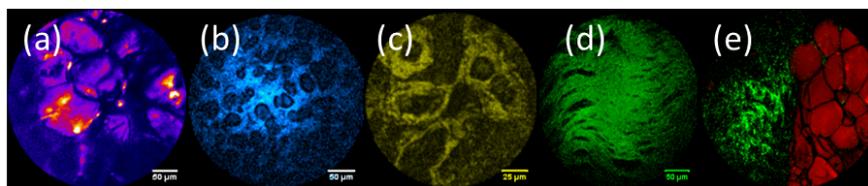


Fig. 2 a) Human colon tissue (CARS); **b)** rat brain (CARS); **c)** mouse liver (CARS); **d)** sciatic nerve (CARS); **e)** colon tissue(CARS in red) and SHG from collagen fibers (green)

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