Enhanced deep detection of Raman scattered light by wavefront shaping

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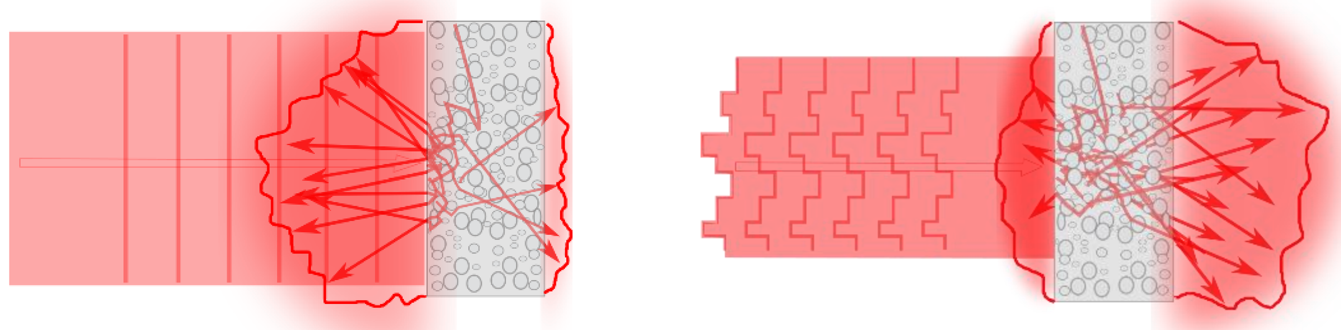
Abstract

Light incident on turbid media cannot penetrate deep into a disordered medium due to multiple scattering. This presents a problem for many fields where optical sensing or energy delivery through scattering media is critical, such as Raman spectroscopy or white LEDs among others. In this work we use wavefront shaping techniques to increase the penetration depth of light in optically thick scattering materials, thus allowing detection of Raman scattering from materials 1.4 times optically thicker than with regular techniques.

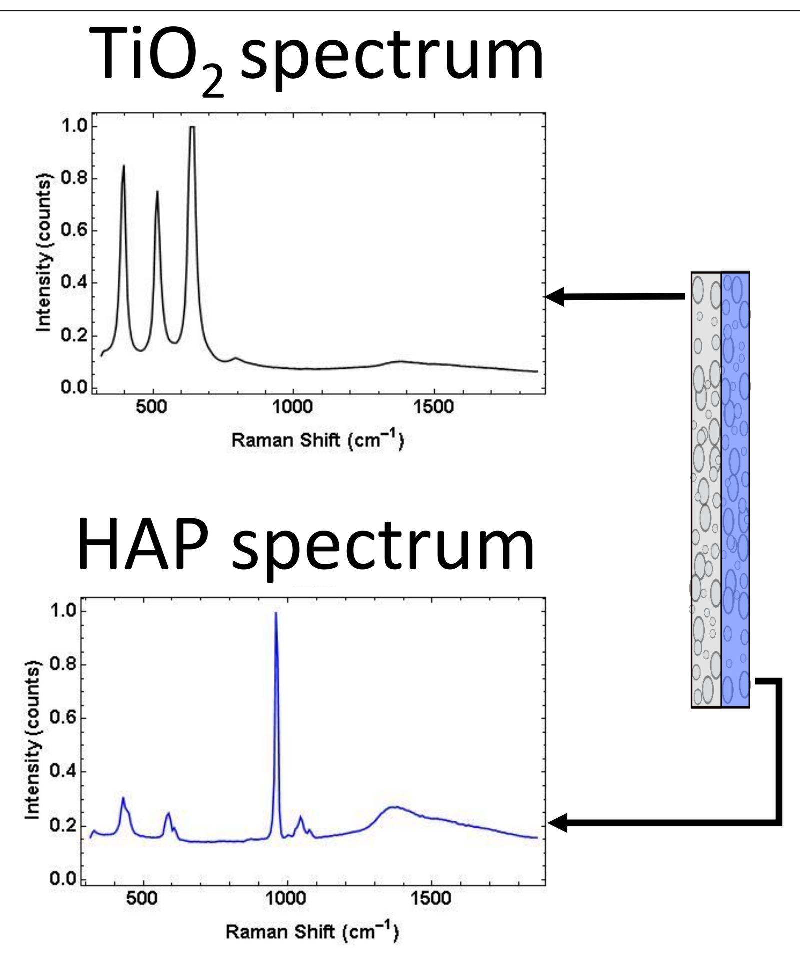
Experimental method

In strongly scattering media, the penetration depth of light is limited to a region close to the illuminated surface (left). However, since elastic scattering preserve coherence, we can control interference by shaping the wavefront of the incident beam[1,2] (right).

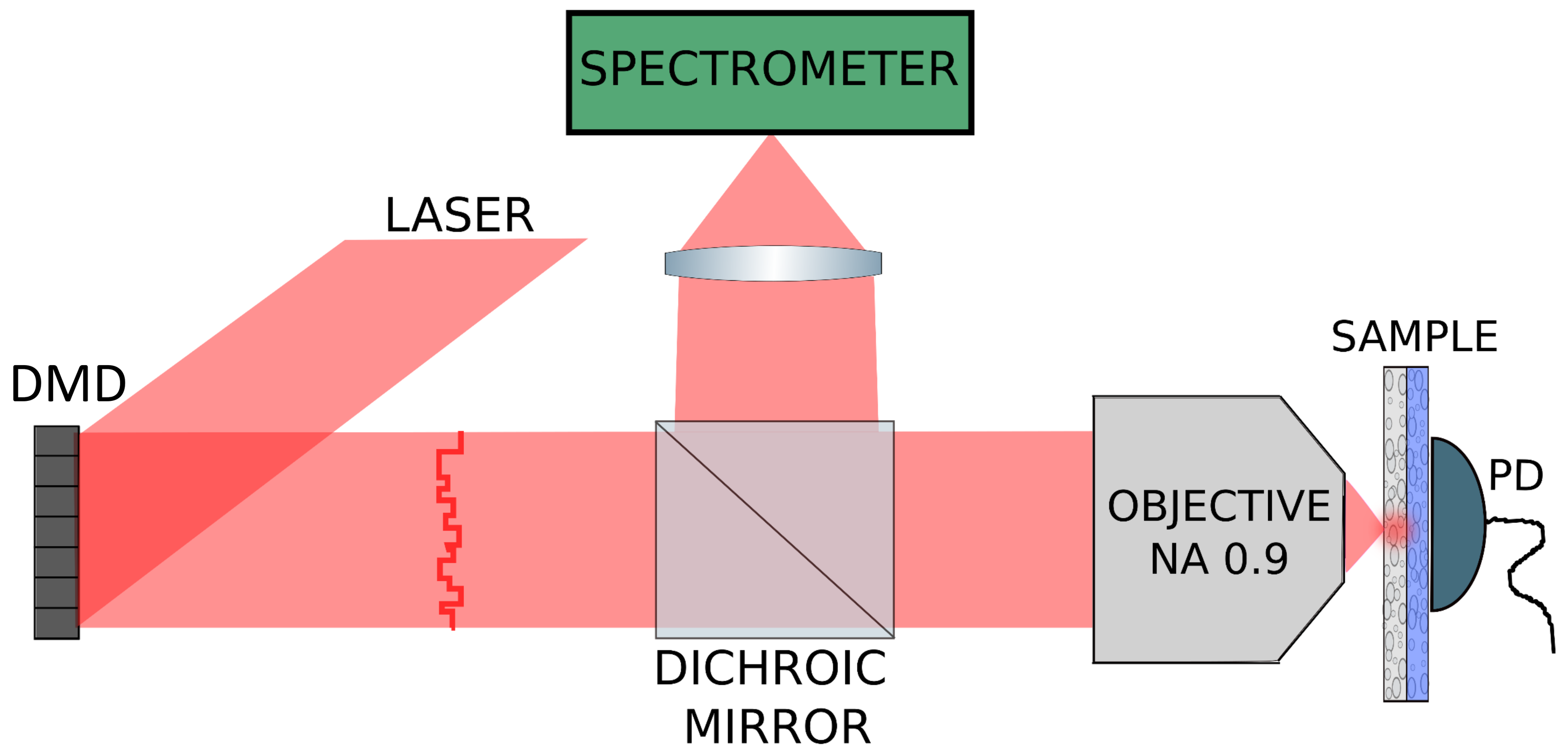


Sample

The sample is made of two layers of different strongly scattering materials: The outer layer of TiO2 and an inner layer of Hidroxylapatite (HAP)



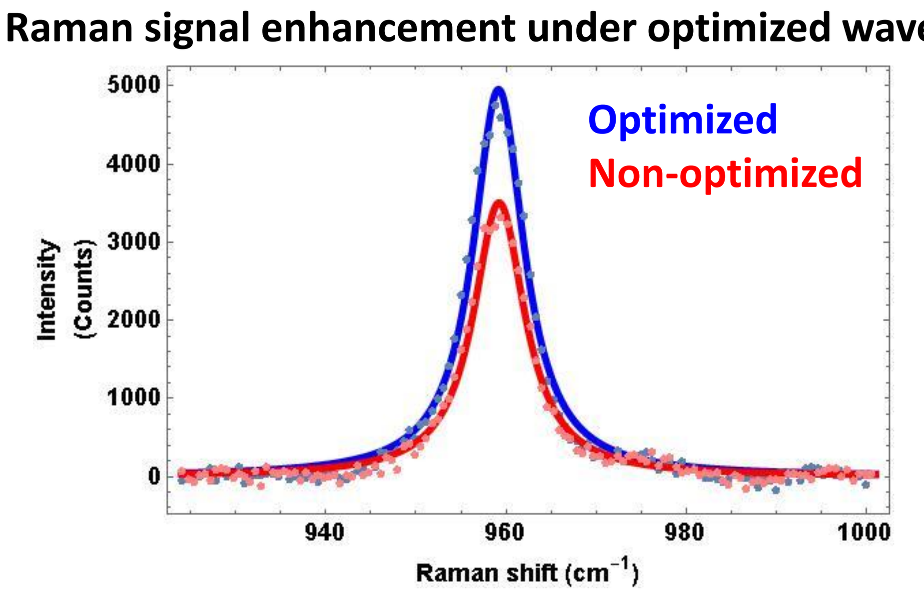
We use a fast Digital Micromirror Device (DMD) to control the phase profile of the pump light incident on the sample. The figure represents a schematic of the experimental setup. Total transmitted light through the sample is optimized using an iterative algorithm that picks the optimal phase on the DMD as the reflected light is collected and analysed by a spectrometer.



Results and discussion

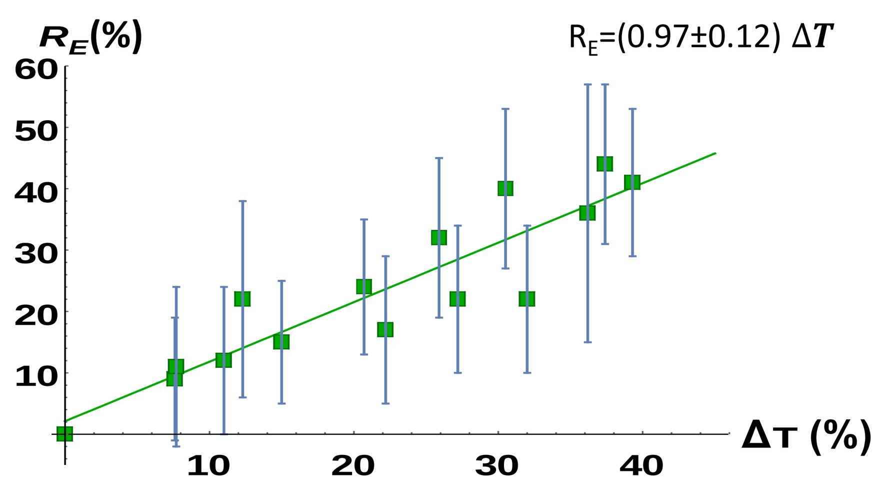
On the left graph we show a maximal increase of 40% in the Raman backscattered light, corresponding to a 40% deeper penetration depth given the linear nature of spontaneous Raman scattering. On the right graph we show the linearity between the increase in the total transmission and the increase in the backscattered Raman signal, showing the capability of controlling the penetration depth of light by wavefront shaping techniques.

Raman signal enhancement under optimized wavefront



Enhancement in the Raman signal of 40% after the wavefront has been optimized.

Raman enhancement vs Increase in transmission



R_E:Raman enhancement
ΔI_T:Increase in total transmission (%)

References

1. I.M. Vellekoop et al., Opt. Lett. **32**(16):2309–2311, (2007)
2. D. Akbulut et al. Optics Express, **19**(5): 4017-4029, (2011)

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