

## RESEARCHERS

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## Optical Signatures of Liquids

The interaction between a laser beam and a liquid induces temperature changes in the laser-exposed area due to the absorbed energy. These localized temperature variations create a refractive-index gradient that deflects a probe beam. By studying the laser-liquid interaction, we can obtain valuable information about the liquid's properties, including absorbance, density, thermo-optic coefficient, heat capacity and thermal conductivity. However, the information is indirectly attained from time- or amplitude-dependent signals,<sup>1-3</sup> which result from the deflection of a single-wavelength probe beam. A drawback of this approach is that external factors can potentially affect these signals.

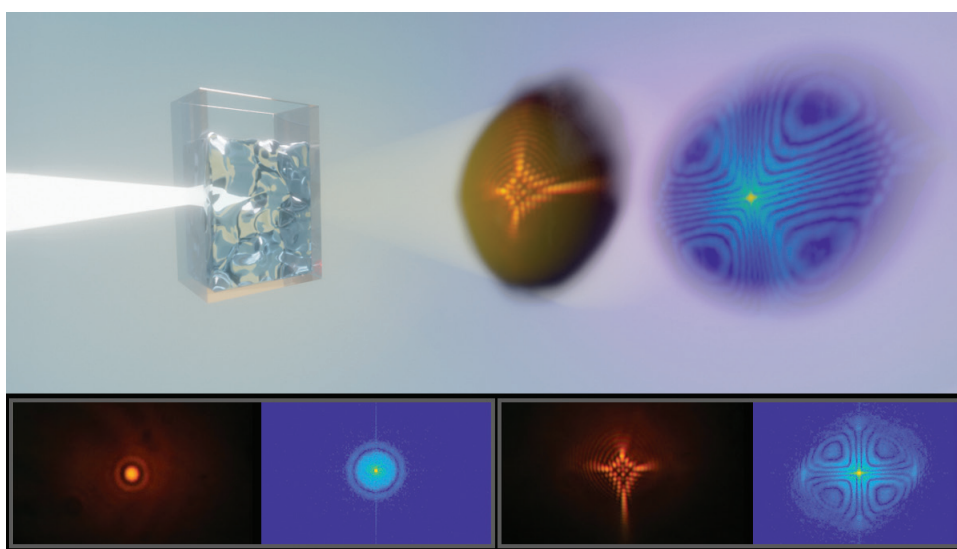
To address the aforementioned challenges and broaden the applications of the photothermal effect, we have studied the interaction of focused femtosecond infrared light with hydrogen-bonded liquids such as water, alcohols and binary mixtures. Our findings revealed that this interaction generates unique diffraction patterns that can be observed with a digital camera and considered the optical fingerprints of the liquid.<sup>4</sup>

In our experimental setup, we employed a 330-fs infrared laser operating at 1040 nm as

the excitation (pump) beam for the liquids. The probe beam was visible light generated with a sapphire crystal exposed to the aforementioned femtosecond laser. The infrared and visible beams were both focused on various liquids, including water, methanol, ethanol and 1-propanol. Femtosecond infrared laser pulses focused in a liquid generate a local refractive-index gradient that is unique to the liquid. This gradient within the sampled region leads to the diffraction of the tightly focused multiwavelength probe beam, which propagates collinearly with the pump beam. We captured the diffraction patterns with a digital camera and subsequently calculated the spatial Fourier transforms.

We have observed that the topology and geometry of the diffraction patterns induced by photothermal effects are influenced by the characteristics of the liquid under investigation. Consequently, these patterns may be regarded as an optical signature of a hydrogen-bonded liquid. Our technique could thus potentially be used for liquid identification, analogous to the use of X-ray diffraction for crystal identification.

Our technique offers an alternative to the nonspecific monitoring of time- or amplitude-dependent signals commonly used in thermal-lens spectroscopy. Its simplicity lies in its compatibility with commercially available supercontinuum sources and digital cameras, which makes it easily implementable. As a result, it holds great potential for practical applications, such as studying hydrogen bonding in various polymers, DNA or proteins. Additionally, it can contribute to the development of compact instruments for point-of-need testing. [OPEN](#)



Top: Schematic of the experimental setup used for studying laser-liquid interactions (left), and resulting diffraction pattern (center) and digital Fourier transform (right) for a methanol sample. Bottom: Diffraction patterns and digital Fourier transforms observed in water (left) and isopropanol (right).