Using digital in-line holography for optical characterization of particles levitated in an acoustic trap.

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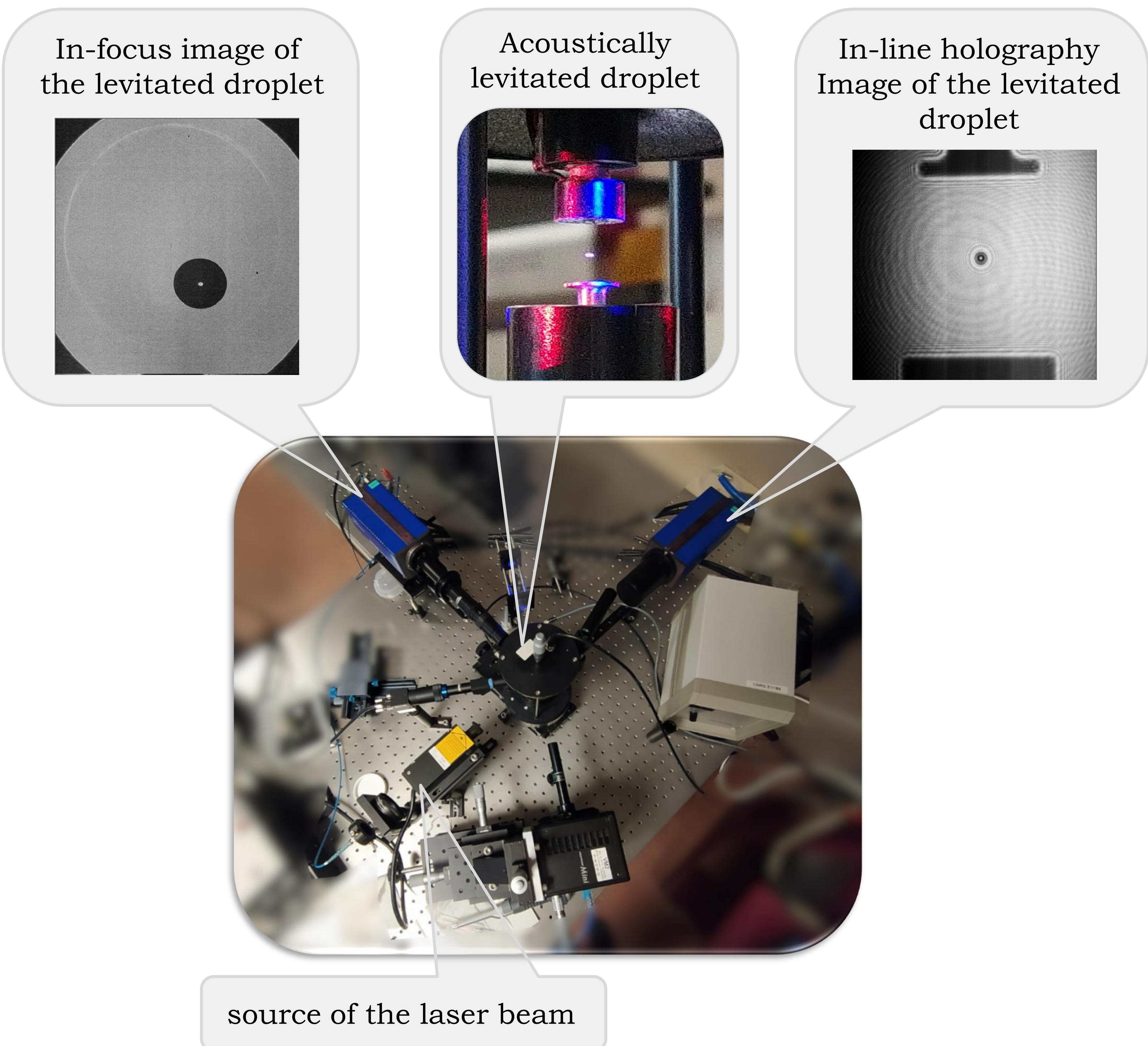
Abstract:

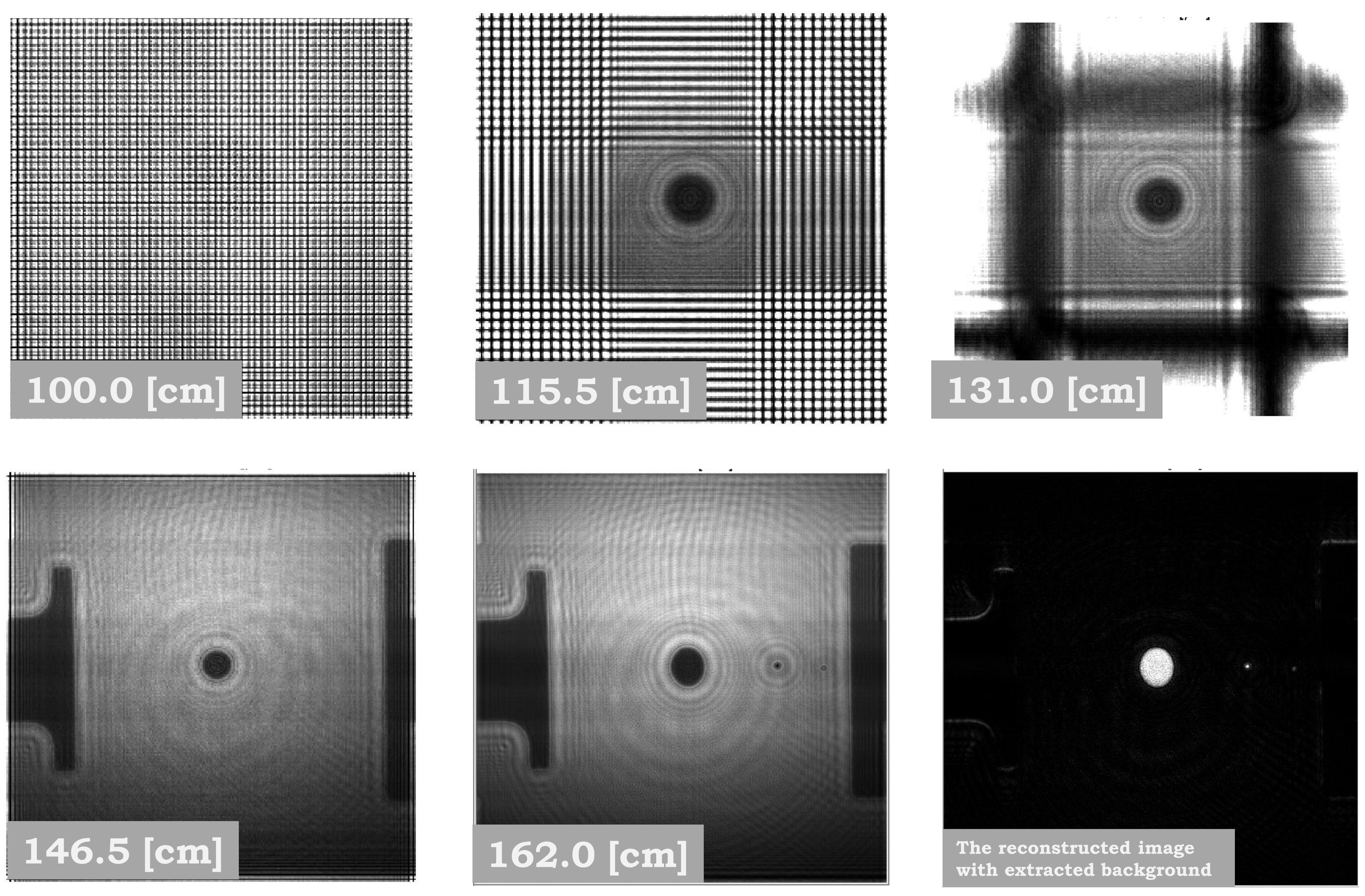
The acoustic levitator is a well-known device that has been widely applied for the study of fluid physics, nucleation, biochemical processes, and various form of soft matter. The acoustic levitator provides a unique environment, a container-free condition that can help to avoid contamination of the studied sample by the container walls and in the case of liquid droplets, studying the internal and surface flow.

Combining the capabilities of contactless manipulation of liquid drops, provided by an acoustic trap and, a volumetric imaging technic, provided by digital in-line holography, we can build the apparatus that allows measuring the 3D position, dynamic, shape, and size of micrometer to millimeter-sized particles. Additionally, compared with conventional imagining technics, digital in-line holography allows for the reconstruction of the wavefront between object and detector. Also, the digital in-line hologram gives access not only to the real image of the object but to the virtual image, which contains information about the phase distribution in the volume of the droplet as well.

Experimental setup



The images of the reconstructed holograms at different distances from the object



Numerical reconstruction procedure

The most common reconstruction methods use discrete Fresnel transformation to calculate the complex amplitude of the diffracted wave in the plane of the real image:

$$\Gamma(m,n) = \exp\left[-i\frac{\pi}{\lambda d}\left(m^2\Delta\xi^2 + n^2\Delta\eta^2\right)\right]\times$$
$$\sum_{k=0}^{N-1}\sum_{l=0}^{N-1} t(k,l)\exp\left[-i\frac{\pi}{\lambda d}\left(k^2\Delta x^2 + l^2\Delta y^2\right)\right]\times\exp\left[i2\pi\left(\frac{km}{N}\div\frac{\ln}{N}\right)\right]$$
$$m = 0,1,\ldots, N-1; \quad n = 0,1,\ldots, N-1$$

where $t(k,l)$ is a matrix of $N \times N$ points that describe the digitally sampled amplitude transmittance of the hologram; λ wavelength of incident beam; d – distance from the objec to the hologram and Δx, Δy and $\Delta\xi$, $\Delta\eta$ are the pixel sizes in the hologram plane and in the plane of the reconstructed image, respectively.

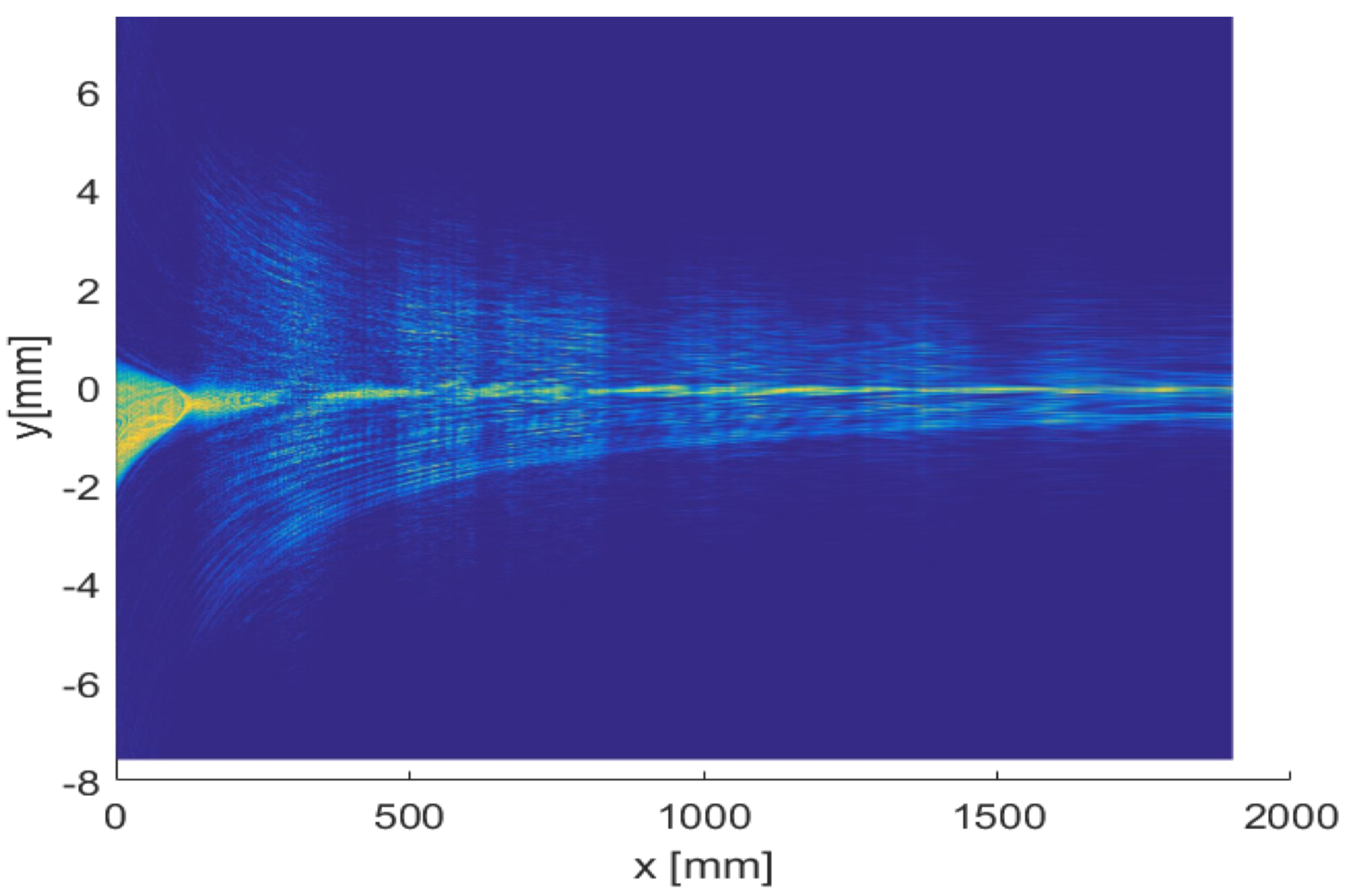
One calculates the intensity from the complex amplitude by taking the modulus and squaring:

$$I(m,n) = |\Gamma(m,n)|^2$$

Essentially, the standard reconstruction procedure as described above can be summarized by the following three steps:

1. Calculate $t(k,l)\exp\left[-i\frac{\pi}{\lambda d}\left(k^2\Delta x^2 + l^2\Delta y^2\right)\right]$
2. Perform an optical FFT, which means a shifted fast Fourier transformation where the low frequency components have been shifted to the image center.
3. Transform the results to an intensity distribution.

The reconstructed image of the photonic jet



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