| ESRF | **Experiment title:** Microsecond multicontrast imaging of the ablation process during laser-based nanoparticle synthesis in water | **Experiment number**: MA3242 |
|---|---|---|
| **Beamline**: ID19 | **Date of experiment**: from: 27-09-2016 01-10-2016 | **Date of report**: 28-02-17 |
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## Report:

During laser ablation of materials into liquid medium nanoparticles are created and ejected in a volume of about 3x3x2 $mm^3$. This material is confined by the formation of a highly dynamic cavitation bubble. The imaging of these structures with high time resolution and sensitivity to sub-micrometer size scales is a challenge [1-4]. By combining ultrafast cameras and a hole array we intended to obtain multicontrast X-ray imaging of this process in order to identify the hierarchical interaction of macro- and nanoscale.

Our approach was a single-shot, multicontrast imaging method with high time resolution. Single-shot means that all image contrasts are recorded within the same instant in order not to be biased by experimental drifts. Therefore we adapted a mask method [5] in order to obtain simultaneous absorption, differential phase and dark field contrast from the ablation process. A pinhole mask is placed in front of the sample such that an array of microbeams illuminates every second (or third) pixel. Then phase contrast and dark field contrast are extracted by deriving microbeam shift or broadening by a full-field Fourier transform process. The distance from sample to detector defines the sensitivity on structure sizes, which ranges for the used setup between 100 and 500 nm [6].

**Experimental setup**:
An existing chamber [4] has been used to immerse the target (gold or silver under flowing water), while a lens couples in a nanosecond laser pulse (1064 nm, 20 mJ, 5 ns; Continuum Minilite I). The illuminated area in radiography was around 5x7 $mm^2$. For the high time resolution a fast CMOS camera (DIMAX) was used at 12.5 kHz frame rate. Interleaving several delays was used to obtain final films of the ablation dynamics with 20 microsecond time resolution.
However, due to the limitation in peak flux the ablation process has to be repeated numerous times and data averaged to improve signal to noise ratio. A further problem in signal-to-noise ratio is the detection of high-energy radiation besides the used direct-beam single line undulator emission of ID19 at 19 keV through the 25 µm platinum hole mask.

**Results:**
Nevertheless we were able to record a representative multicontrast data set of the ablation process (2 orders of phase contrast=shift of the pinhole beams + 2 orders of diffraction contrast= broadening of the pinhole beams) from gold target as well as several films with bright field with propagation phase contrast. An example of data is shown in the figure 1 below.
The absorption contrast is taken from the bright field with full resolution, while phase contrast and diffraction contrast have the resolution of the pinhole mask. It is clear that the hemispheric vapor

bubble seen after a delay of 120 µs after laser impact on the target (bottom image border) shows a phase contrast feature particularly when a change in refractive index crosses the direction of the image analysis (direction of Fourier analysis).

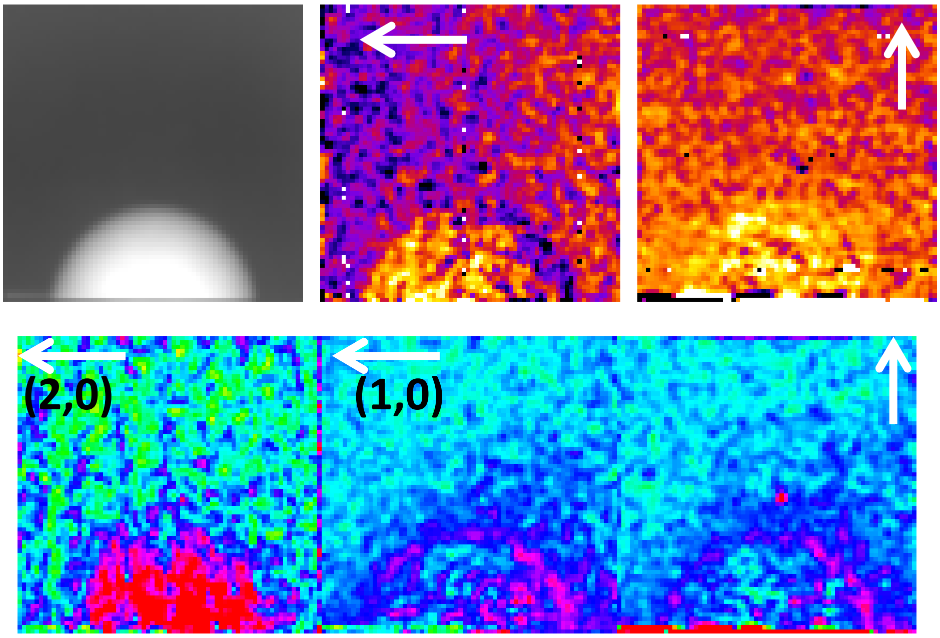


**Figure 1:** *Multicontrast imaging of the transient cavitation bubble at 120 µs delay: top row from left: absorption, horizontal phase contrast, vertical phase contrast. Bottom row from left: Second order horizontal diffraction, first order horizontal diffraction, first order vertical diffraction. The arrow marks the direction of sensitivity. The image field is about 4x4 mm.*

Apart from the phase contrast the different orders of diffraction contrasts show a signal, which is mostly located close to the liquid-vapor interface of the bubble. The higher order (larger structures) shows a signal within the bubble. The data sets are being analysed and correlated to lab screening experiments. Part of the data has been published [7].

**References:**


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