One-shot imaging of laser-induced surface acoustic waves on silicon and metal films using pump-probe microscopy

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Pump-probe microscopy is an essential tool for studying laser-matter interaction. However, the imaging of laser-induced surface acoustic waves (SAWs) has not been possible with a conventional setup. In this study, we present a new approach to detect SAWs with a conventional setup and discuss the mechanisms behind it.
The pulses emitted by an ultrafast laser source with a wavelength of 1040 nm and a duration of 380 fs were divided into pump and probe pulses. The probe pulses were frequency-doubled to 520 nm and optically delayed up to 20 ns. The pump and probe pulses were coupled into the microscope via a dichroic filter and a polarizing beam splitter, respectively, to achieve coaxial upright irradiation and illumination of the sample through the same microscope objective (Nikon CFI P-Achromat 20X/ 0.40/ 1,20) (see sketch in Fig. 1a). The convex lens in the sample beam path, which was originally intended to focus the probe pulse on the parfocal plane of the microscope objective for collimated illumination of the sample (Fig. 1b), was shifted here by about 10 mm (Fig. 1a, Pos A to Pos B) to make the SAWs visible.
In this configuration, the background intensity decreases significantly (see Fig. 1c and 1f). The effect becomes even stronger as the intensity of the probe pulse increases. In the difference images, the SAW, which is invisible in the standard configuration (Fig. d), becomes clearly visible around the crater and the shock wave front in air (Fig. 1g). SAWs recorded on silicon show directionally dependent velocities, and on platinum films with 30 nm and 200 nm single and multi-mode features, respectively.
The larger lens distance causes the reflected light to be focused into the microscope objective, as sketched in Fig. 1e. The intensity-dependent effect, which reduces the image brightness, indicates that non-linear absorption occurs in the microscope objective. This could act as a background filter, while the light reflected from the waves could take a different path and be less attenuated, so that the SAWs finally become visible in the difference images. In future, this effect could provide new insights into the phenomena of laser-matter interaction, photoacoustic effects, especially at high intensities, and materials science.

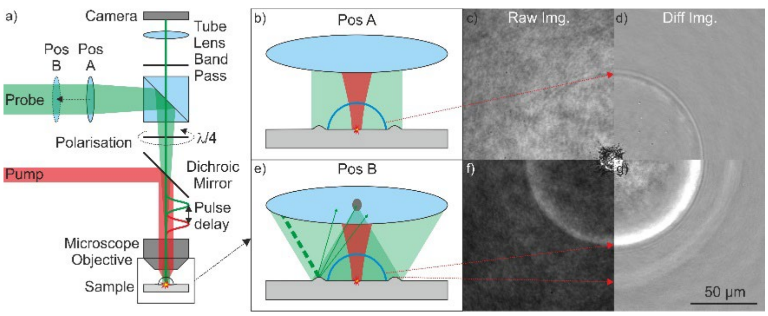

Figure 1: a) Sketch of the pump-probe microscope, illumination conditions with convex lens in b) Pos A and e) Pos B, and corresponding raw c) and f) and difference images d) and g) of silicon.