Speckle Pattern Interferometry

Laser interferometry is used for measuring displacements along an axis with nanometre resolution. The deformation of a rough surface can be measured using a *Digital Speckle Pattern Interferometer* (DSPI). The laser light reflected from the object surface develops a stochastic intensity pattern, the so-called *speckle pattern*. Interfering this pattern with a reference beam allows to measure displacements with a CCD-camera in multiples of the laser wavelength λ. If the object is illuminated from different directions, Fig.1, all three Cartesian components of the deformation field can be obtained. To induce the deformation, mechanical, thermal, and vibrational loading can be applied.

Specifications:

Laser wavelength	532	nm
Laser power	5	W
Maximum object size	0.6 x 0.8	m^2
Minimum object size	24 x 32	mm^2
Best resolution	2	nm
Measurement uncertainty	> 20	nm
Measurement range per load step	< 20	µm
Modal analysis (time average)	0.5 – 70	kHz

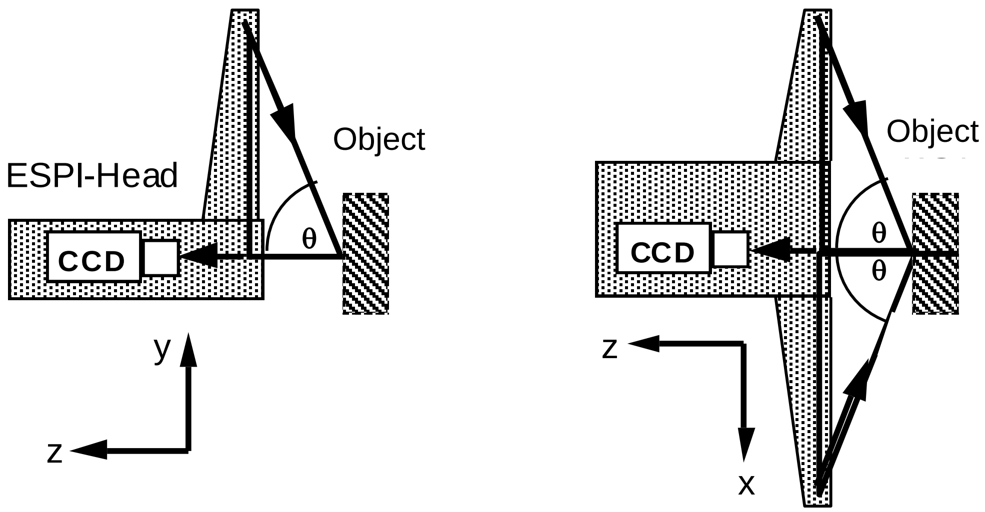

Fig. 1: Illumination of an object from three directions and definition of the axes, schematic.

DSPI for 3D-deformation analysis

The measurement of all three Cartesian components of the deformation is a prerequisite for a full characterization of the mechanical behaviour under load (Fig.2). These results form the basis for a comparison to FE-analyses (Fig.3) and the calculation of strain fields (Fig.4).

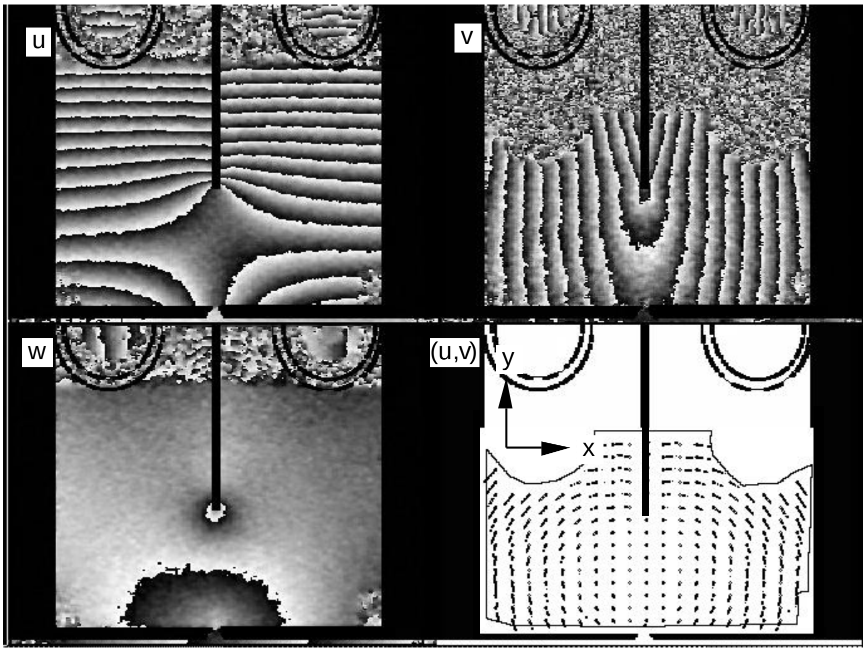

Fig. 2: 3D-DSPI analysis of a wedge-splitting test. The phase images depict lines of equal deformation in x-, y-, und z-direction. The arrow graph summarizes the deformation in the x-y plane (surface plane). Resolution is 0.52 µm for each interference fringe in-plane (u, v) and 0.44 µm out-of-plane (w), respectively.

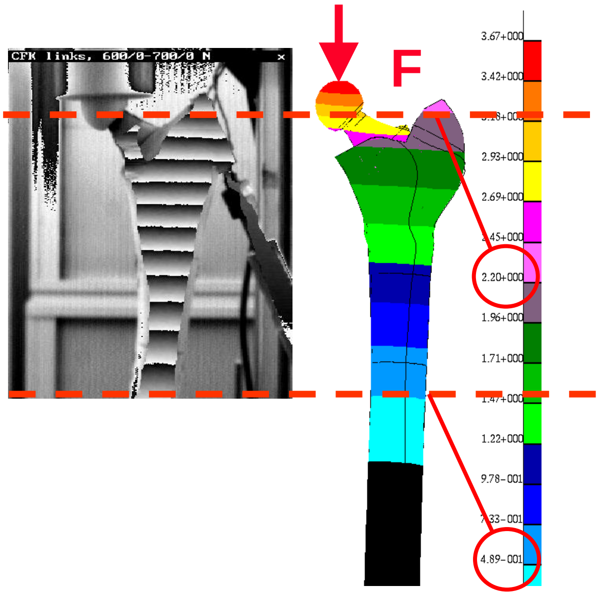

Fig. 3: Measurement and simulation of the bending line of a hip prosthesis mounted into a femur model.

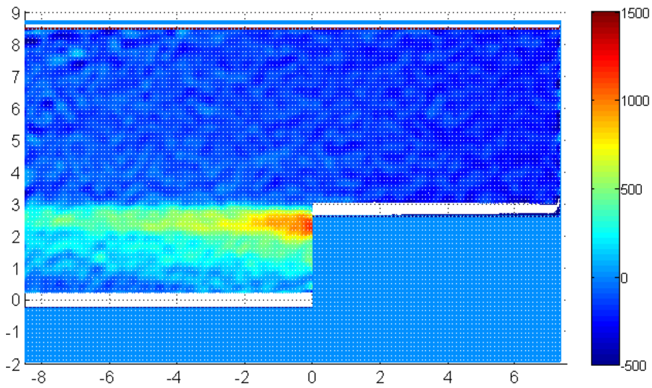

Fig. 4: Shear strain at the edge of a CFRP reinforcement (in µm/m).

DSPI for NDE

Due to the extremely high sensitivity of this interferometric method tiny deviations in the deformation behaviour can be spotted. This lends DSPI as a method for non-destructive evaluation (NDE), because defects cause such deviations in the surface deformation fields (Fig.5) even at low loading levels well below the critical value.

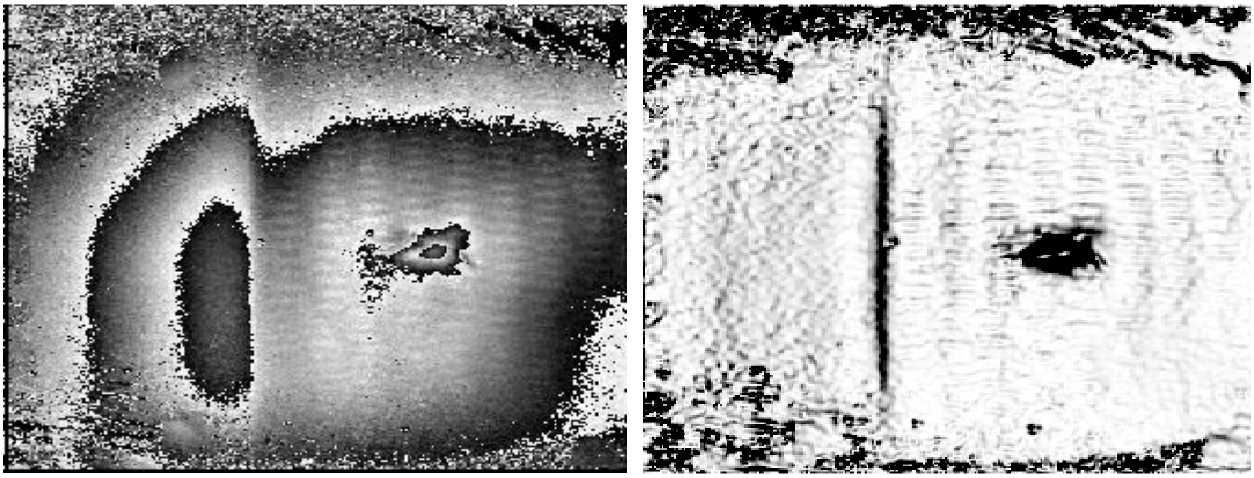

Fig. 5: DSPI analysis of an impact damage on the European Robot Arm (ERA, to be mounted on the International Space Station). Left: surface deformation after thermal loading. Right: Phase gradient image for better localisation of the defected area.

DSPI for modal analysis

Using stroboscopic illumination resonance frequencies can be identified and the corresponding mode shapes can be measured (Fig.6).

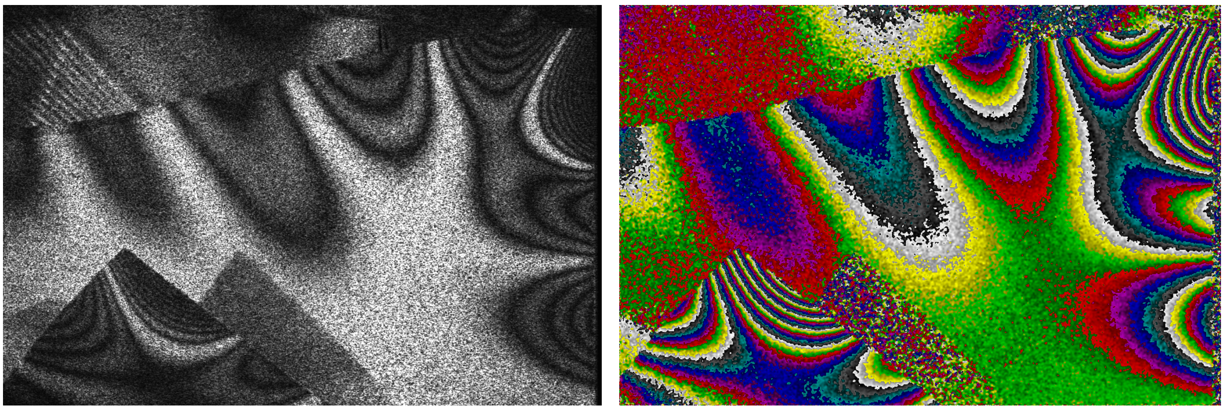

Fig 6: Modal analysis of a compressor blade at 11.85 kHz. Left: Modal shape as seen in the time-average mode. Nodal lines appear as bright areas. Right: Quantitative analysis of peaks and valleys. One fringe (contour line, white to white) corresponds to 0.3 µm of surface vibration amplitude.