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Optical Fibre Probe Microscopy

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In the optical fiber probe microscope (Cerre et al. 1991), light is launched into a single mode optical fibre and is incident on the object (Fig. 1). The reflected light is coupled back into the fibre, and after passing through a fibre coupler its intensity measured with a photodiode detector. An image is built up by scanning the fibre tip relative to the object surface. This can be ach-ieved by mechanically moving either the fibre tip or the object itself. The strength of the light coupled back into the fibre depends on the reflectivity of the sample, but also its distance from the fibre (i.e. the surface height) and the tilt of the surface. In practice there is also a reflection of light from the fibre tip, which results in interference fringes being formed as the object is scanned in depth. The interference pattern consists of fringes within an envelope defined by upper and lower parts. Investigation of the details of the interference allows us to extract the various properties of the surface at the particular scan point. In this way it is very similar to the confocal surface profiling methods, except that in the present case there is no peak in intensity because the radiation from the fibre is divergent rather than convergent.

The light emerging from a single mode optical fibre is closely approximated by a Gaussian beam. The variation in intensity along the axis is proportional to $1/(1+(z/z_0)^2)$, where z is the distance from the beam waist, located at the fibre tip, and z_0 is the confocal parameter.

If there is a sample in front of the illuminating fibre tip, a fraction of the light can be reflected from the sample surface back towards the fibre. Part of this light couples back into the fibre, whilst the rest is reflected by the fibre tip back to the sample. Thus multiple reflections are set up, similar to a Fabry-Perot resonator. For the particular case when the normal to the sample surface is parallel to the axis, i.e. when r=0 in Fig. 2, experimental results have been presented previously (Fatemi and Sheppard 1993, Sheppard et al. 1995). It is possible to measure the geometrical parameters of the light emitted from the fibre, e.g. z_0, by observations using a plane mirror as sample.

In the present study, we examine the effects when the surface is tilted, so that $\gamma \neq 0$. We assume that the value of z_0, and thus the far-field angle of divergence, θ, and also the amplitude reflection coefficient γ_0 of the fibre tip, are known. The aim is to measure the amplitude reflection coefficient r of the sample, and the local tilt of the sample surface. The method is valid when the illuminated surface can be assumed locally plane. Spatial resolution is thus limited to about

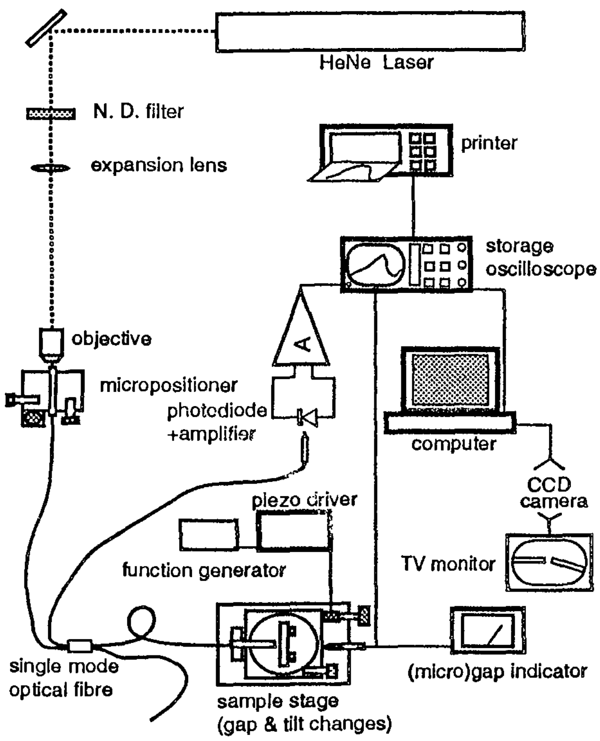

Fig. 1. A schematic diagram of the optical fibre probe microscope.

the fibre spot size, which is around 3 μm in our experiments.

In order to investigate the behaviour of the signal with different sample parameters, we used a tilted mirror as sample.

The fibre tip is viewed and positioned relative to the sample surface (Fig. 2), and can be tracked from side and top views through an image grabbing system. For a given surface tilt the axial position is scanned using a feedback-controlled pie-zoactuator, driven by a sawtooth generator. The signal is digitally accumulatea in a storage oscilloscope and processed using a computer. Fig. 3 shows an example of an experimental plot. The figure covers the lower part of the envelope of the interference fringes, the geometry of which can be used to extract the reflectivity and tilt of the sample. An important property which is observed is the zero of the lower part of the envelope. The existence of this zero limits the measurements to a value of r greater then 0.2. In practice this covers a wide range of industrial and biological samples.

We have also been experimenting with different geomtries of fibre tip, including angled polishing, and the formation of tapers and microlenses.

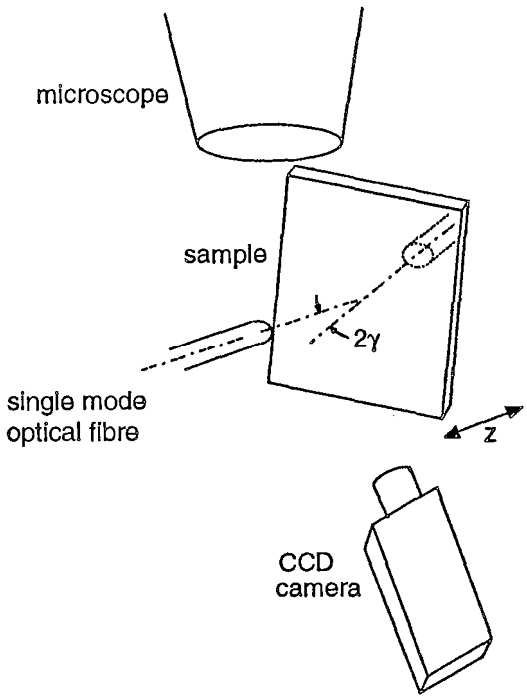

Fig. 2. A close-up of the fibre tip and sample.

REFERENCES

Cerre N, F de Fornel, JP Goudonnet. 1991. Reflection scanning microscopy. Applied Optics. **31:** 903-908.

Sheppard CJR, H Fatemi, Min Gu. 1995. The Fourier optics of near-field microscopy. Scanning. **17:** 28-40.

Fatemi HEG, CJR Sheppard. 1993. Topographic studies of reflecting surfaces by means of a single-mode optical fibre. Australian Conference of Optics, Lasers and Spectroscopy. Melbourne: Proceedings, p.70.

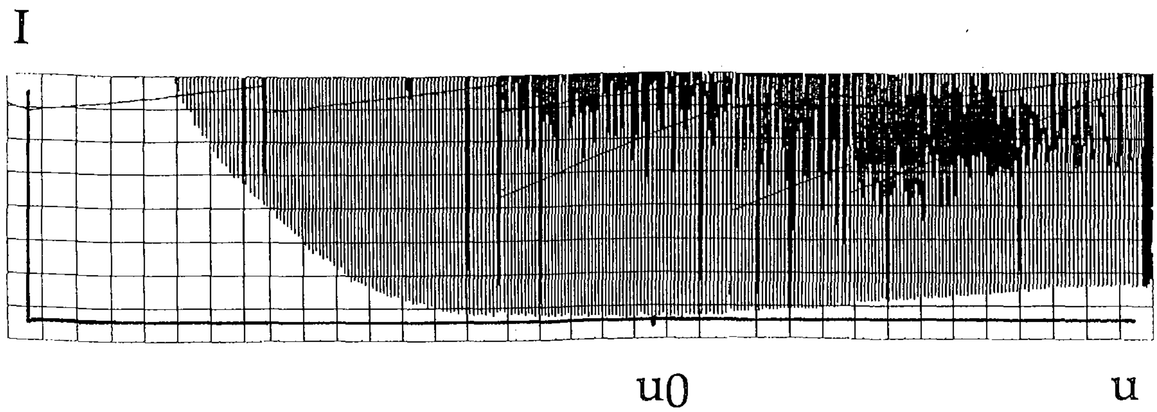

Fig. 3. An example of an interference pattern from a mirror as sample. The lower part of the envelope is shown, depicting a zero in the envelope.