Comparison of AF/RSNOM with other RSNOM

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AF/RSNOM is a new kind of scanning probe microscope developed in our lab, which is a combination of atomic force microscope and reflection scanning near field optical microscopy (AF/RSNOM) working in equi-amplitude tapping mode. This paper introduces the principle of AF/RSNOM and its advantages compared with other reflection mode scanning optical microscopes (RSNOM). Compared with the former RSNOM, this tapping mode AF/RSNOM has convenient operation and fewer background signals.

OCIS codes: 110.0110, 180.0180, 120.0120, 110.0180.

The future of near-field optical microscopy probably lies in the direction of using optical frustration to analyze a surface. RSNOM is one kind of this near-field optical microscope. Several kinds of RSNOM systems have been developed recently, such as side illumination while vertical collection mode systems[1] or *vice versa*[2−4] and so on[5−10]. These RSNOM usually work in shear force mode or contact mode. The AF/RSNOM introduced in this paper works in an equi-amplitude tapping mode, which uses a bent optical fiber tip as both illumination and collection elements. This dual-functional probe tip makes the adjusting of illumination source and collector needless. At the same time, this AF/RSNOM can obtain both the reflected light average intensity image $\bar{I}(x,y)$ and the reflected light intensity gradient image $\Delta I(x,y)$ simultaneously.

The principle of this tapping mode AF/RSNOM is illustrated in Fig. 1. LD1 and LD2 are two laser diodes used as optical cantilever and sample illumination sources respectively, whose wavelengths are 632.8 nm. PSD is short for position sensitive device, which receives the optical signal reflected by the probe cantilever during imaging process, and this signal will be dealt with to form the sample's topography image. The laser beam emitted by LD2 is coupled into mono-mode optical fiber and comes out from the bent fiber tip to illuminate the sample, then the dual-functional fiber probe tip receives some of the scattered laser beam and send them to the optical signal processor where the signals will be dealt with to form the sample's optical images. These images include the reflected light average intensity image $\bar{I}(x,y)$ and the reflected light intensity gradient image $\Delta I(x,y)$. The vibrator drives the fiber probe to oscillate vertically in sine wave at the resonance frequency of the vibrator and the probe adhered on it above the sample surface. The amplitude (A) of the oscillation is usually about 20 nm during scanning, which is smaller than the $\lambda/4$ for the 632.8-nm illumination wavelength. That is to say, the fiber probe tip works in the evanescent field of the sample surface, and the collected optical signals are near-field signals of the sample that carry the sample's high resolution information. It is known that the electromagnetic wave attenuates exponentially in the evanescent field, so the obtained optical signal varies with the changes of the oscillating tip position, and this tapping working mode makes it possible to get the reflected light average intensity image $\bar{I}(x,y)$ and the reflected light intensity gradient image $\Delta I(x,y)$.

Several kinds of RSNOM are illustrated in Fig. 2. Figure 2(a) is side illumination and vertical collection mode RSNOM; Fig. 2(b) is vertical illumination and side collection mode RSNOM; Fig. 2(c) is side illumination and collection mode RSNOM, the tip plays the role of a perturbing element for the electromagnetic field; Fig. 2(d) is shear force control while vertical illumination and collection mode RSNOM; Fig. 2(e) is an example using an objective as collection element.

The main drawback of the method of Fig. 2(a)–(c) is the unsymmetrical illumination (or collection) device used in the system, this asymmetry signal will bring arti-

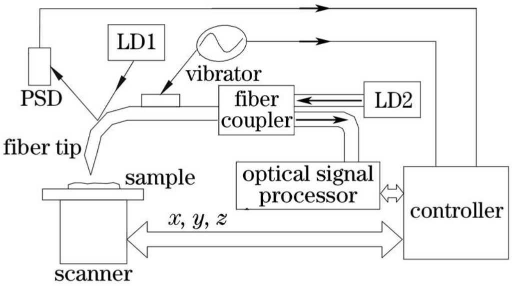

Fig. 1. Principle of tapping mode AF/RSNOM.

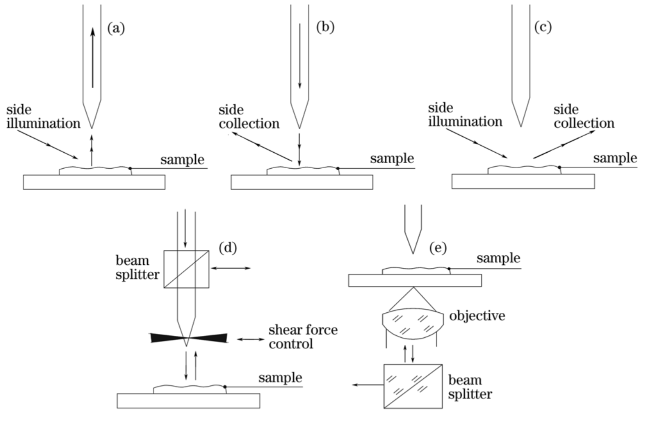

Fig. 2. Several kinds of RSNOM sketch maps. (a) side illumination and vertical collection mode RSNOM; (b) vertical illumination and side collection mode RSNOM; (c) side illumination and collection mode RSNOM; (d) shear force control while vertical illumination and collection mode RSNOM; (e) RSNOM using an objective as collection element.

facts in sample's optical image and will bring difficulty in getting enough sample's high resolution information because of the strong background reflected signals. At the same time, the advantage of Fig. 2(a) lies in that the signal used is the near-field optical which carries near-field information of sample.

For the system where the probe tip is mainly used as perturbing element for the electromagnetic field, the technique is connected to the Photon-STM technique[11]. It works whatever the related tip, (metal, metal coated, transparent dielectric, AFM tips etc.). This kind of system is often called apertureless microscope, such as Figs. 2(c) and (e), the optical signal collected with this technology is the far field information mixed with near field information of the sample.

For the R-SNOM consists in using the same fiber probe both to illuminate the sample and collect the light in the near-field of sample (see Fig. 2(d) and Fig. 1). The technique carries some similarities with the confocal microscope. Its main advantage is the ability to combine local illumination and local collection. It seems, from a simple experimental point of view, that only the axial rays will be able to propagate back through the tip[11]. This simplistic explanation is in agreement with rather good results obtained in various places. Besides above advantage, this technique has convenient operation, because the dual-functional probe tip makes it needless to adjust the illumination and the collection elements. Compared with shear force control system of Fig. 2(d), tapping working mode AF/RSNOM has the superiorities of both the ability to reduce the damnification to sample and the ability to get gradient optical signal. What's more, tapping working mode makes it convenient to reduce the background signal, and thus to increase the signal to noise ratio (SNR)[11].

Conclusions can be drawn from above analysis. First, AF/RSNOM is one member of SPM that represents the direction of future near-field optical microscopy using optical frustration to analyze a surface, it collects only the axial rays of sample' near-field information with the dual-functional probe tip, this obtained light intensity gradient image has a better SNR ratio than other RSNOM dues to its tapping working mode. Second, AF/RSNOM has the ability to get higher image resolution because the signal of $\Delta I(x, y)$ is mainly composed of evanescent wave that carries the super resolution message of sample, and this will bring AF/RSNOM a bright future. Third, the dual-functional probe tip of AF/RSNOM brings an even illumination for every sampling position, and this will reduce artifacts for asymmetry illumination. Besides above advantages, AF/RSNOM has easy operation and sample preparation because it almost fits to all kinds of SPM samples.

This work was supported by the National Natural Science Foundation of China (No. 60007011) and the China Ministry of Technology Instrument Function Exploitation Foundation (No. GN-99-15). Y. Li's e-mail address is amlyl2003@163.com.

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