Atomic Force Microscopes Employing Laser Beam Deflection for Force Detection*

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The principle of scanning probe microscopes (SPM) was first described by J. A. O'Keefe in the 1960s. In 1982, the scanning tunnelling microscope (STM), the first supreme example of SPM family, was developed[1]; for which Binnig and Rohrer received the 1986 Nobel Prize in Physics. Shortly after that, in 1986 Binnig together with Quate and Gerber introduced the first atomic force microscope (AFM)[2]. Unlike the STM, the AFM images the sample topography by measuring the faint interatomic forces between a flexible stylus and surface of the sample. It offers an added advantage over the STM for which the sample need not be a conductor, and hence has been used in science and technology more widely. Up till now, the AFM has been developed into a very important new technique for surface studies.

In 1988, the AFM was improved by using the optical level technique. Topographic images of the surfaces of samples are produced by measuring the change in angle of laser beam reflected off the back of the cantilever while scanning. This improvement resulted in the development of the laser-AFM (AFM employing laser beam deflection for force detection)[3-5]. The laser-AFM not only avoids the tunnelling junction pollution, but also works more stable and reliable than the tunnelling AFM. On the other hand, it reduces the tip-to-sample force, so it fits studying the soft materials such as biological molecules. The first atomic-resolution laser-AFM was developed by the scientists of University of California, USA and other units in 1989[5].

On the basis of our previous STM and AFM[6-7], we have developed the first laser-AFM in China. The lateral resolution of our laser-AFM is 0.13 nm, which reaches the atomic resolution. On December 10, 1992, our laser-AFM passed the expertise of

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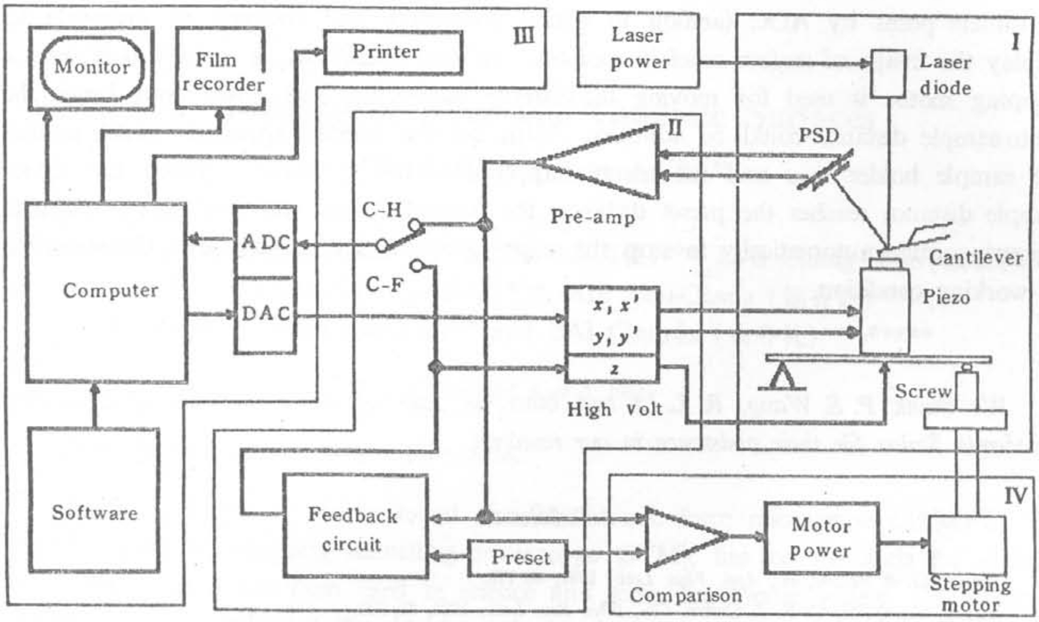

Fig. 1. Laser-AFM system schematic. I, Laser-AFM stage; II, circuitry; III, computer system; IV, motor controller. PSD, position-sensitive detector; C-H, constant-high; C-F, constant-force.

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As shown in Fig. 1, our laser-AFM consists of four parts, namely the stage, the circuitry, the computer system and the motor controller. The stage is depicted in Fig. 2. Laser beam from laser diode is focused on the cantilever with lens. The reflected light at the cantilever is reflected by a mirror and falls on a position-sensitive detector, a two-segment photodiode, thereby converted to an electrical signal. The electrical signal is amplified by pre-amplifier, and then transmitted to the feedback circuit. The digital signal from the computer is converted to the analog signal by DAC (digital to analog converter). The analog signal is fed to the high voltage amplifier which drives the PZT (piezoelectric transducer) tube to scan across xy plane. Taking effect of the feedback circuit, the z-axis motion of PZT tube compensates for the undulation

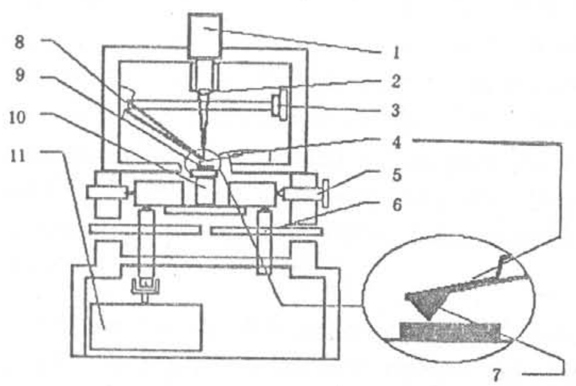

Fig. 2. A simple schematic of laser-AFM head. 1, Laser diode; 2, lens; 3, detector; 4, cantilever; 5, sample positioner; 6, sample approach screws; 7, tip; 8, mirror; 9, sample; 10, piezo; 11, stepping motor.

of the sample surface. The computer collects the output of feedback circuit in every *xy* coordinate point by ADC (analog to digital converter), and converts to grayscale to display the image of surface relief in monitor. In our laser-AFM, a screw driven with a stepping motor is used for moving the sample holder up and down and hence the tip-to-sample distance could be adjusted. Turn on the sample approach switch so that the sample holder rises and the sample approaches the cantilever. When the tip-to-sample distance reaches the preset distance, the control system will send out a negative triggering pulse automatically to stop the stepping motor immediately, and the system is in working condition.

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