## Lateral Resolution in Scanning Force Microscopy

Brian A. Todd and Steven J. Eppell Case Western Reserve University bat5@po.cwru.edu

Two particular questions keep coming up regarding Atomic Force Microscopy (AFM), and we would like to address them here.

## What exactly is the definition of "lateral resolution" of atomic force microscopy?

The lateral resolution of AFM is a parameter that currently has no accepted definition. The definition used in our lab is "the minimum distance between objects at which you can distinguish distinct objects." In other words, imagine a surface with two sharp features: upon bringing the two features closer and closer together, at some point only one object is seen. That distance is the resolution limit. It is useful to define "see" as having a dip in height greater than the noise level in the image.

In optics, this is analogous to the Rayleigh criterion (aka the Abbé diffraction limit). In this case, a hole in an optically opaque plane with a size near the wavelength of light causes a pattern to appear on the focal plane that consists of a series of concentric

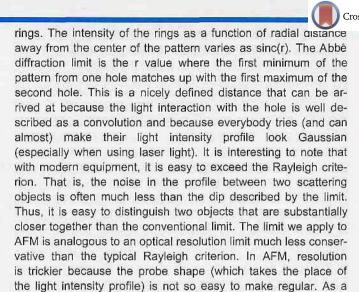
## MICROSCOPY TECHNICIAN

St. Lawrence University seeks a microscopy technician. This is a full-time, 12-month academic support staff position. A bachelor's degree in science (preferably in biology) is required. A master's degree and/or experience with confocal microscopy as well as electron microscopy (TEM and/or SEM) are preferred. The successful candidate should show evidence of mechanical and laboratory aptitude, computer experience, a desire to learn and teach new methods, and a positive work ethic.

The successful candidate will help oversee a developing interdisciplinary, multi-user microscopy/imagery center, will assist faculty and student researchers in advanced microscopy techniques, help teach microscopy methods and provide for the routine maintenance of the instrumentation infrastructure. The major instruments at the facility are on service contracts and the candidate will be expected to develop good working relationships with the professional service personnel. The facility is housed in the biology department and the successful candidate will also serve other science departments.

Applicants should send a letter of application, a current curriculum vitae (including references), if appropriate, a statement of any relevant research and teaching interests related to microscopy, and have three letters of recommendation forwarded to Dr. T. Budd, Biology Department, St. Lawrence University, Romoda Drive, Canton, NY 13617. The search committee will review applications until the position is filled.

For more information please visit SLU's homepage at <a href="http://www.stlawu.edu/resources/job.html">http://www.stlawu.edu/resources/job.html</a>. SLU is an AA/EO employer. Women, minorities, veterans, and persons with disabilities are encouraged to apply.



ent on the geometry of the particular probe in use.

All of the papers that deal with these issues that we are aware of address accuracy but not resolution.

quickly jumps up to several nanometers and is strongly depend-

general rule, the shape will be different along every line drawn

through the apex of the probe. In addition, the width of the

probe varies as a function of height up from the apex. Thus,

AFM resolution will depend on the height of the objects meas-

ured and the geometry of the specific probe used. For imaging

atoms that protrude less than an Ångstrom above the image plane, the lateral resolution of AFM can be below 1 Ångstrom. For objects that are a nanometer or two tall, this resolution limit

## What is the difference between the "radius of curvature" of an AFM tip, and the "tip radius"?

The term "curvature" is a well defined mathematical concept found in most analytic geometry textbooks and it is:

$$K = \frac{\left| \frac{d^2 y}{dx^2} \right|}{\left( 1 + \left( \frac{dy}{dx} \right)^2 \right)^{\frac{3}{2}}}$$

So, if one has an AFM tip and takes a cross section through the tip, there is a well defined curvature at each point along that line. There is another object called the "circle of curvature" which is the circle tangent to the function at the point of interest and having a curvature equal to the function. It turns out that the radius of this circle is  $1/\kappa$ . People often talk about the "radius of curvature" of their AFM tips, which is an offshoot of this rigorous mathematical concept. What they do is to fit the best possible circle to a cross section taken near the apex of their tip. They then call the radius of this best fit circle the "radius of curvature."

A more cavalier use of the term "tip radius" is used when thinking about the tip as a cylindrically symmetric object. Then, at each position up from the tip apex, the distance from the z-axis of the tip to its surface is reported as the "tip radius."

Some examples of sphere and parabola fits to reconstructed nanosensor SFM probes are at: http://home.cwru.edu/~bat5/research/sfm\_probes/nanosensors.html The tip radius for the sphere fit and the radius of curvature for the parabolic fit are generally pretty comparable.