Tapping Mode Exam

General Knowledge

1) Draw and label a diagram showing the basic components of a standard beam bounce AFM, including the sample, stage, probe, piezos, laser, position sensitive quad detector, and feedback electronics. Label the probe substrate, cantilever, and tip. Indicate where the laser should hit the probe. Circle the components that make up the feedback loop.

2) Briefly explain the general principle behind tapping mode AFM, also known as intermittent contact AFM, AC AFM, or amplitude modulation (AM) AFM. Include a description of how the probe is actuated, how tip-sample interactions are sensed, and the feedback mechanism or setpoint employed. How is tapping mode different from PeakForce tapping (ScanAsyst)?

3) Compared to PeakForce tapping (ScanAsyst) mode, would you typically use a probe with a higher or lower force constant for tapping mode? What is the typical range of force constants for tapping mode probes? (Be sure to include units!)

4) Why do you maximize the “sum” and minimize the vertical and horizontal “deflection” of the laser spot on the quad detector photodiode prior to engaging (i.e., what does this accomplish physically and why is it beneficial to the experiment)? How long should you typically wait for the laser to warm up for optimal stability?

5) In order to carry out a tapping mode scan, you must first tune the probe.
   a. Explain what is meant by “tuning”.

   b. What probe-dependent data must you manually enter (or at least check) prior to carrying out an auto or manual tune? Where do you locate this data?

   c. Sketch a "good" tuning curve. Label the axes. What mathematical function should approximately describe the curve? If the initial tune is poor, what are some simple steps to try and improve the tune?

   d. What is meant by the term “thermal tune”? How is this different from the auto or manual tune you typically carry out?

6) What is the purpose of Bruker's default setting of offsetting ~5% to the left of the tuning curve resonance peak? If you do this, will you be operating in the attractive or repulsive regime when you engage? Explain your reasoning. What would happen if you instead excited the cantilever at a frequency to the right of the peak? Hint: keep in mind the difference between operating frequency and setpoint!

7) To minimize both tip wear and the likelihood of false engages or losing the surface, how should you go about adjusting the engage settings and setpoint? What parameters should you always check before starting the engage process (and what should their values be)?

8) After engaging in tapping mode with an Engage Setpoint of 1.10, you notice the piezo monitor is illuminated red and has the maximum voltage applied to the piezos. What is the proper course of action?

9) What parameter(s) can be adjusted to bring the height trace and retrace lines closer together? Explain how you would go about optimizing the tracking and gains.

10) Before acquiring a large area image, it is often desirable to quickly optimize the scan parameters while imaging a smaller area. Circle which parameter(s) should be held constant between the two images for this method to work. Explain your reasoning.
    a. Scan Rate
    b. Tip Velocity
    c. Samples/Line

11) What are the meanings of the "amplitude" and "phase" channels in tapping mode AFM? What information can be gleaned from these data channels?

12) Suppose you obtain a new AFM probe from the probe cabinet in the SSL. If you subsequently decide to return the probe to its original box in the cabinet, what should you do to document its status? Why?

Tool Specific Values

13) What is the difference between open loop and closed loop scanners? Which kind of scanner is present on each of the 3 AFMs (D3100, MM8, and Icon/FastScan) in the SSL? How does this affect AFM operation (in particular, the use of the zoom and offset functions)?

14) What is the maximum scan size in the X and Y directions for **each** AFM head/scanner? Is this affected if you are using offsets? Why or why not? What is the maximum Z range? Explain what limitations this places on samples and the use of large area scans.

15) What is the maximum image size (X by Y in pixels) for each of the 3 AFMs in the SSL?

16) Suppose you are using a probe with a 5 nm nominal radius of curvature to acquire a 5 µm square (i.e., aspect ratio of 1.0) image. How many Samples/Line should you choose to take full advantage of the image resolution offered by the probe? Suppose instead you are attempting to acquire a 30 µm square image. What is the maximum image resolution achievable (in nm)? What limits/determines this value?

17) What is the nominal noise floor of the system(s) you will be using? What external factors can affect the noise floor and what can be done to minimize them/optimize the z-resolution of the AFM?

Dimension 3100

18) After maximizing the sum signal and zeroing the horizontal and vertical deflection signals on the Dimension 3100, what can you do to determine whether the laser spot is indeed hitting the cantilever on the back of the probe tip, rather than farther back towards the base?

Icon/FastScan

19) If the laser spot icon and actual laser spot are offset in the video image on the Dimension Icon/FastScan, what should you do? How can you determine and select the proper laser spot size on the Icon/FastScan?

20) Bruker's FastScan probes exhibit significantly higher natural resonance frequencies than traditional tapping mode probes.
    a. How is this achieved, and why is this advantageous?

    b. Can you use FastScan probes on other AFMs (or with the Icon head)? Why or why not?

Noncontact Tapping

21) Sketch a plot of the tip-sample interaction forces as a function of tip-sample separation (z-piezo height). Label the attractive and repulsive regimes, and indicate which regime is used for regular tapping and which is used for noncontact tapping.

22) Sketch a plot of the cantilever resonance frequency as a function of tip-sample separation (z-piezo height).

23) What is meant by "noncontact" tapping? Use the plots in the previous two questions to explain how it works, in particular how its implementation is different from normal tapping mode AFM and what the resultant advantages and disadvantages are.

24) What is the typical/acceptable range of probe drive amplitudes (in mV) necessary to achieve a 200 mV target amplitude with a FastScan A probe? What is the typical target amplitude range (in nm) used during noncontact tapping imaging? How large a drive amplitude (in mV) is usually needed to achieve this? How do these values compare to normal tapping?