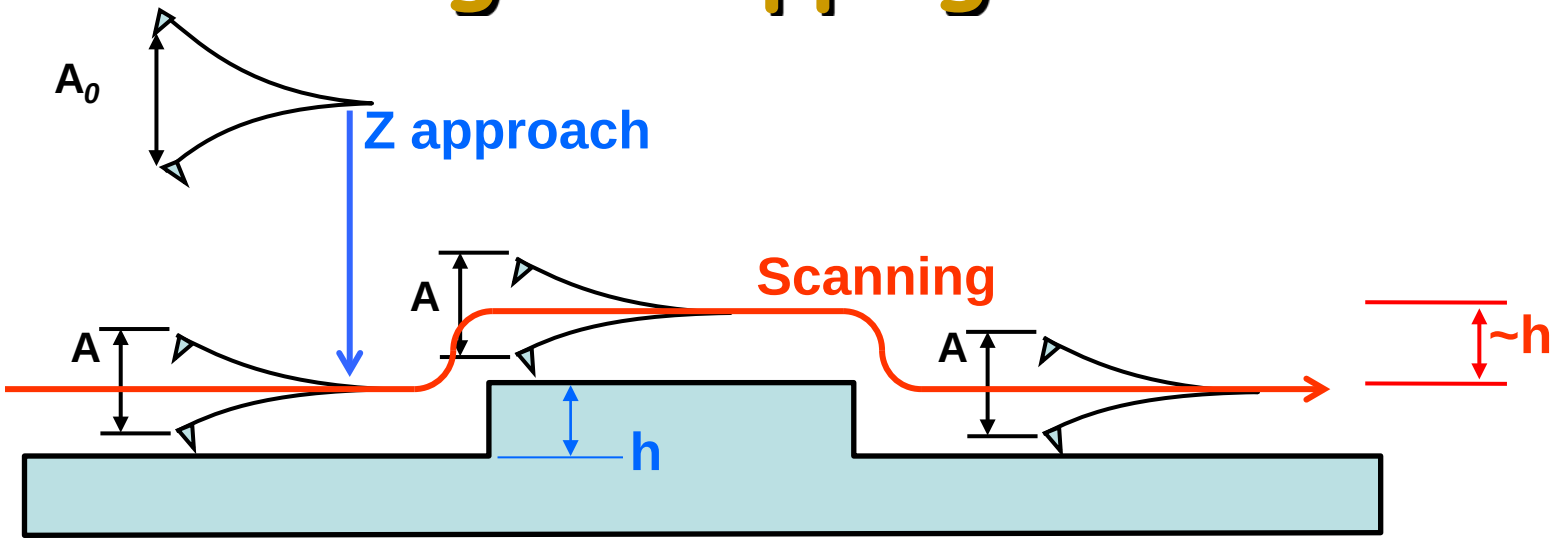
Lecture 19
VEDA: Scanning controls

Arvind Raman
Mechanical Engineering
Birck Nanotechnology Center

Scanning in tapping mode AFM



Questions

- How does the Z controller work? How does a lock-in work?
- How to optimize it for good performance?
- Desired amplitude setpoint A_{sp}, difference between amplitude and desired amplitude is error signal

$$e(t) = A - A_{sp} \qquad Z(t) = -K_P e(t) - K_I \int_0^t e(\tau) d\tau$$

- Analog controller (see VEDA manual for digitial version)

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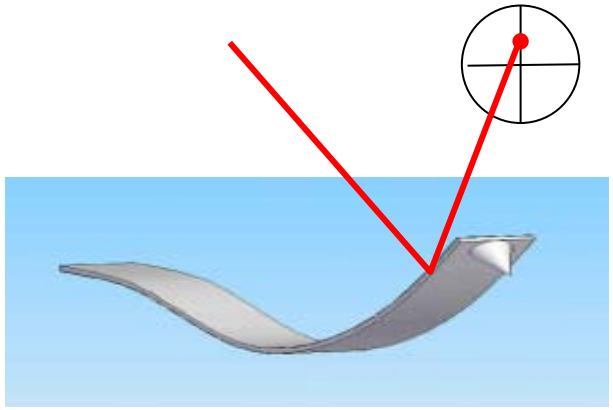
Lock-in amplifier



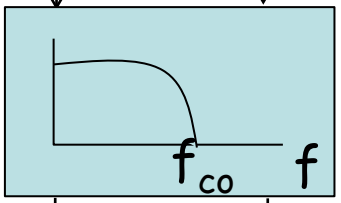
Signal conditioning

$A_0 + A \cos(\omega t - \phi) + A_2 \cos(2\omega t - \phi_2) + \ldots + \text{noise}$

$\cos(\omega t)$

Drive signal

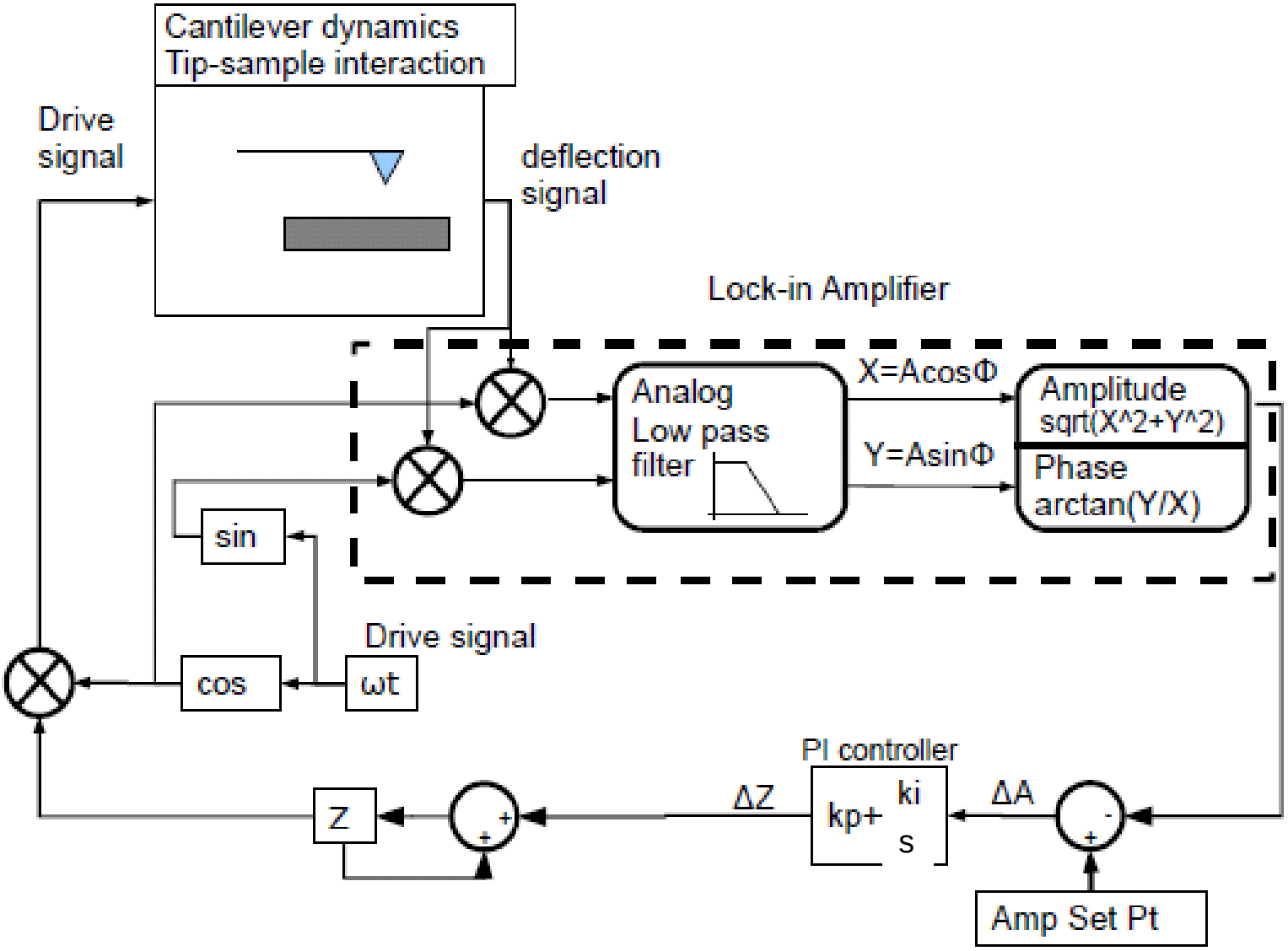
$\sin(\omega t)$



- $T_{lockin} = 1/f_{co}$
- Ideally $f_{co} \ll \omega$ to reduce noise
- However, smaller the T_{lockin}, longer the time to filter

$A \cos(\phi)$ $A \sin(\phi)$

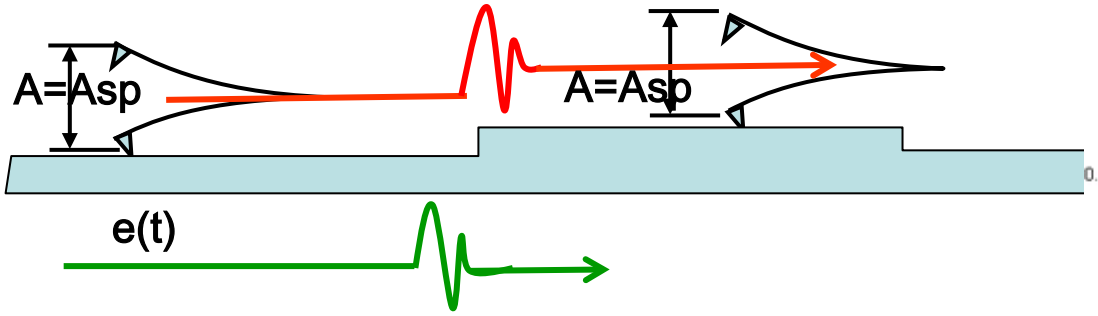
Feedback control in AM-AFM

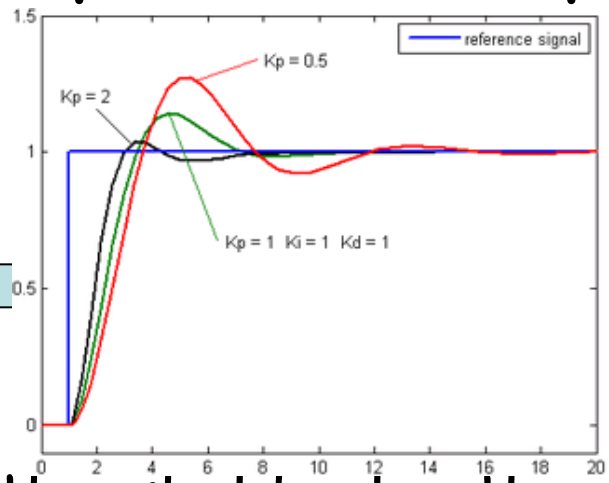


Role of Kp and Ki

$$Z(t) = -K_P e(t) - K_I \int_0^t e(\tau) d\tau$$

- Kp controls how fast Z responds to step changes in topography



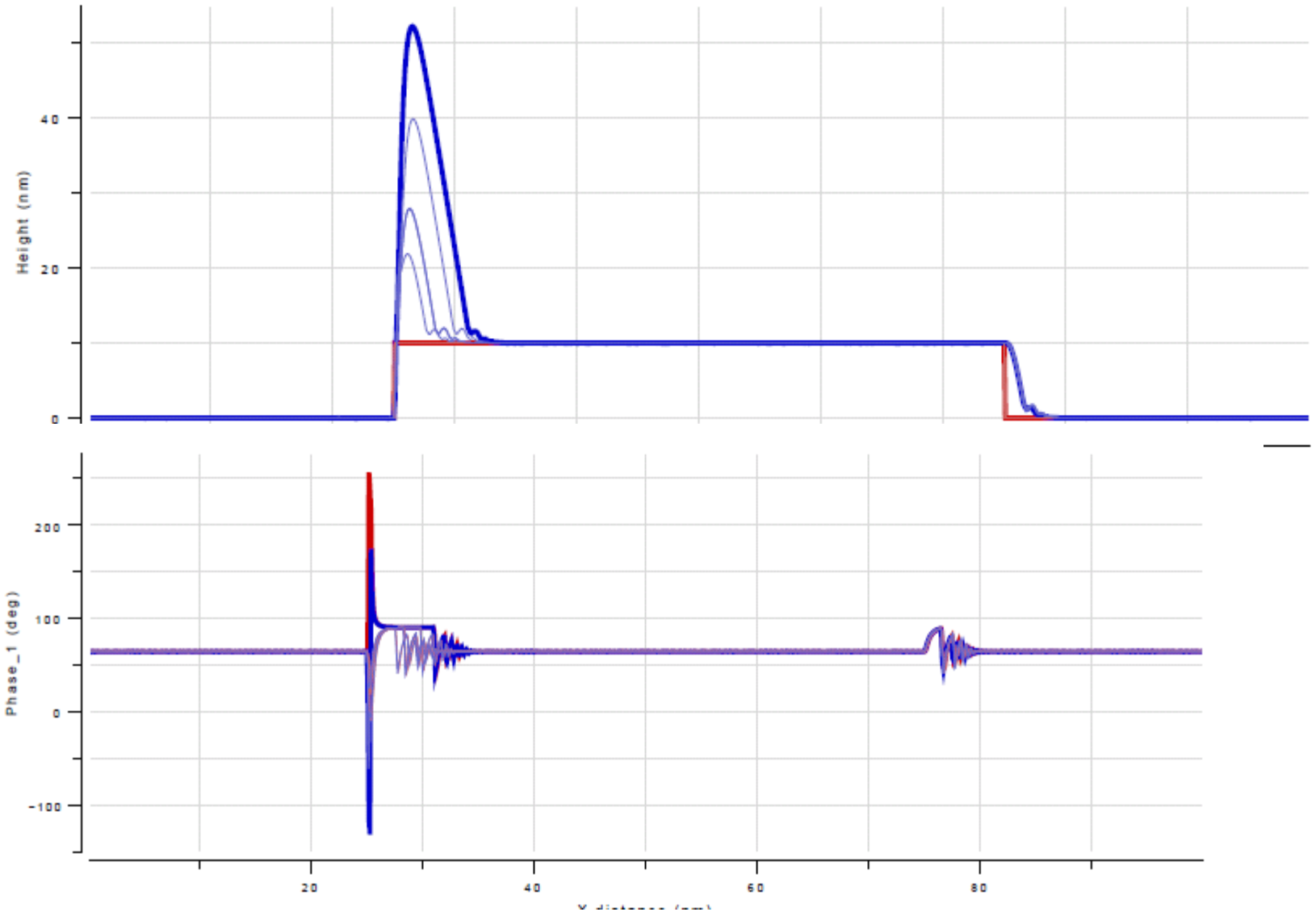


  - However once Kp crosses a threshold value the controller becomes unstable!
  - However one has a steady state error which depends on Kp and cantilever dynamics i.e. if e(t) is very small, there is very small controller output and one has a steady state error
- Integral term Ki ensures steady state error=0

Problem 1 – how do Kp and Ki influence imaging?

- Load example 1 in AMS (basic) tool
- Change feature to step of length 50 n m and height 10 nm (scan size 100nm)
- Keep $Kp=10^{-6}$ and increase until Kp=0.1 in steps
- At each value, check to see if probe remains in repulsive/attractive regime, and check imaging forces and phase
- At what value of Kp does the controller become unstable?

Solution to problem 1



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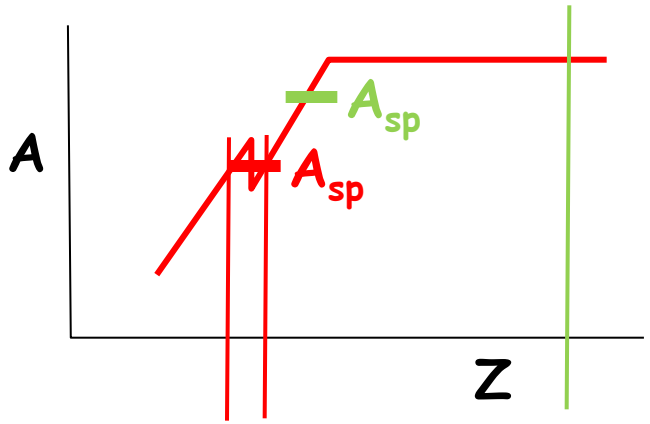
Instability between 0.1<Kp<0.5

Two problems



- Error saturation during tip-sample interaction loss during parachuting. When parachuting off an edge whose height is $>A_0$, the error saturates
- Attractive-repulsive jumps create problems with global stability of controler

Next time

- VEDA simulations of Scanning tool