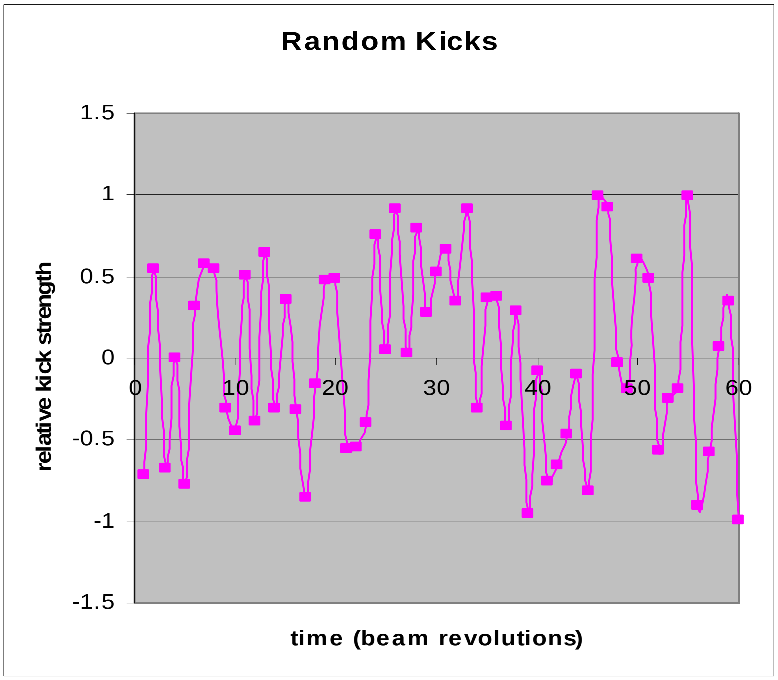
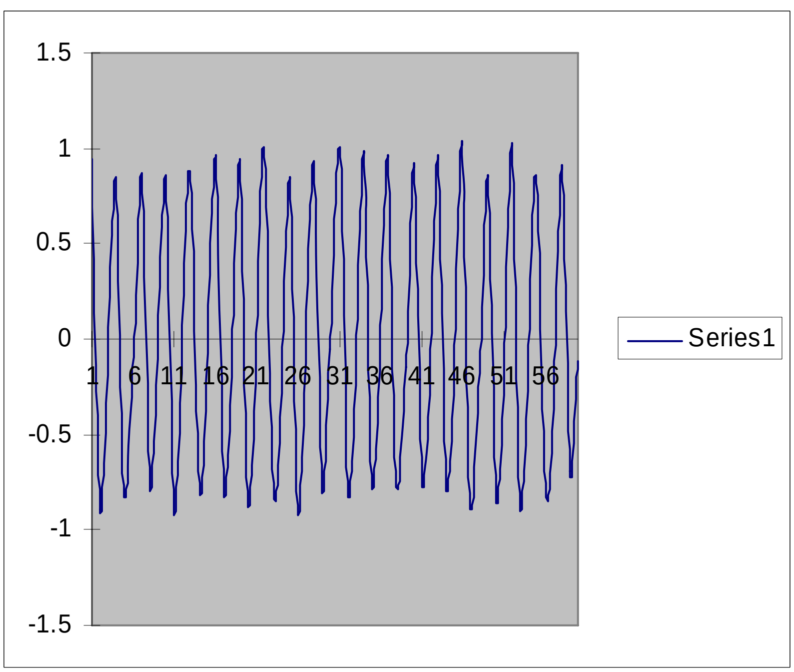
PLL Tune Tracking

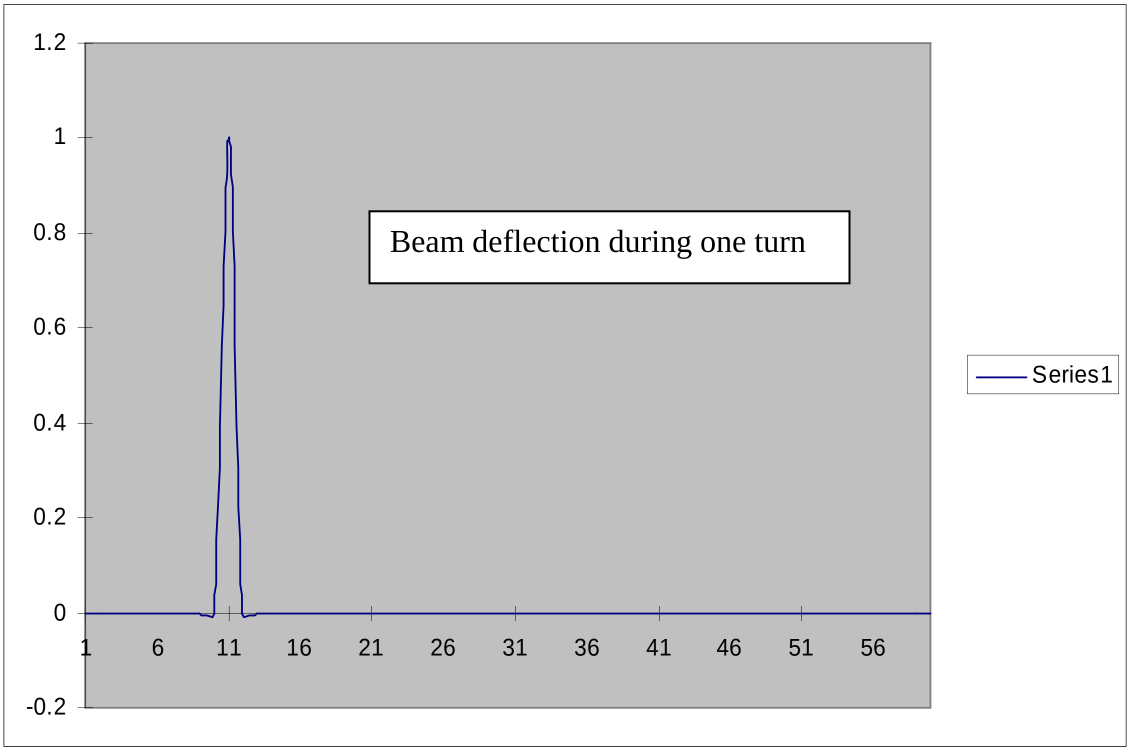
Answers to questions

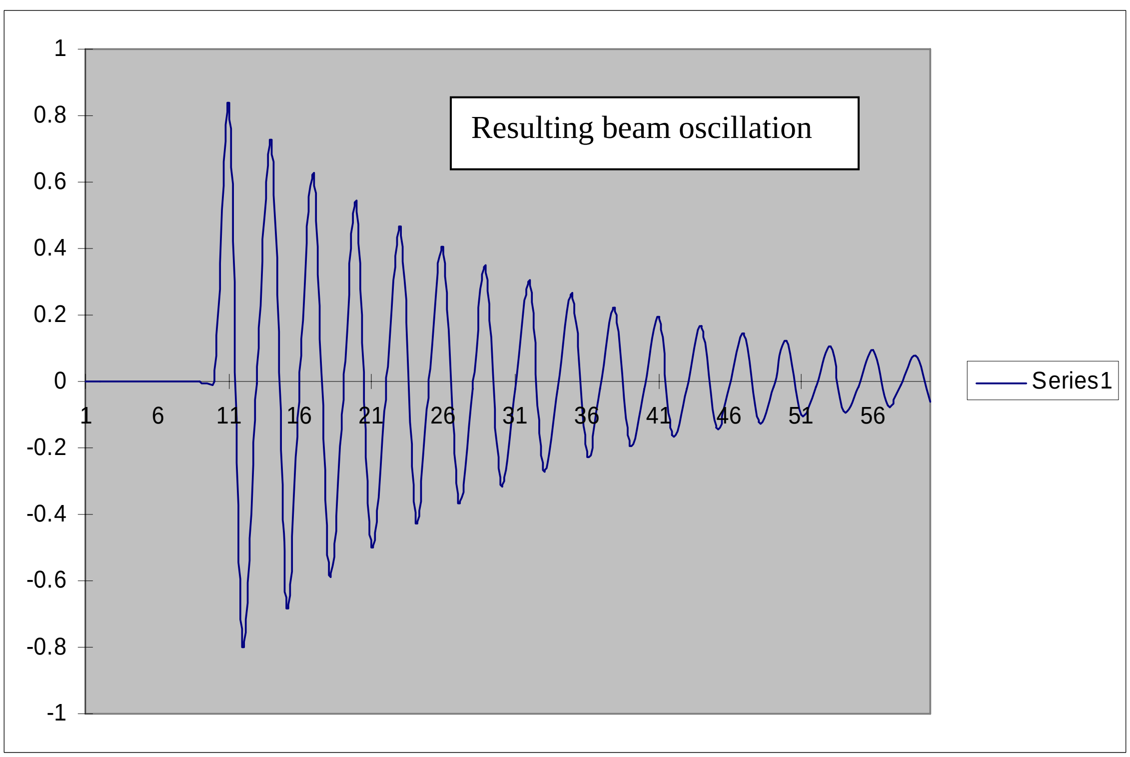
Solutions 1:
a) random kicks and (noisy) sin-oscillation of beam



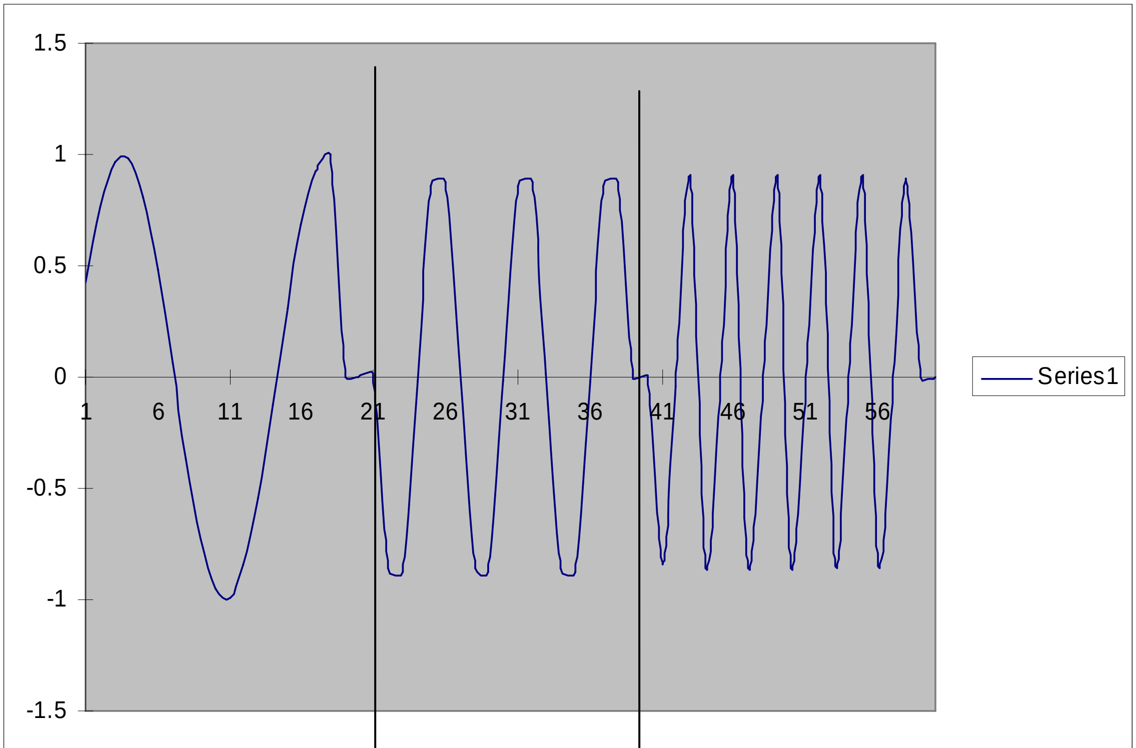


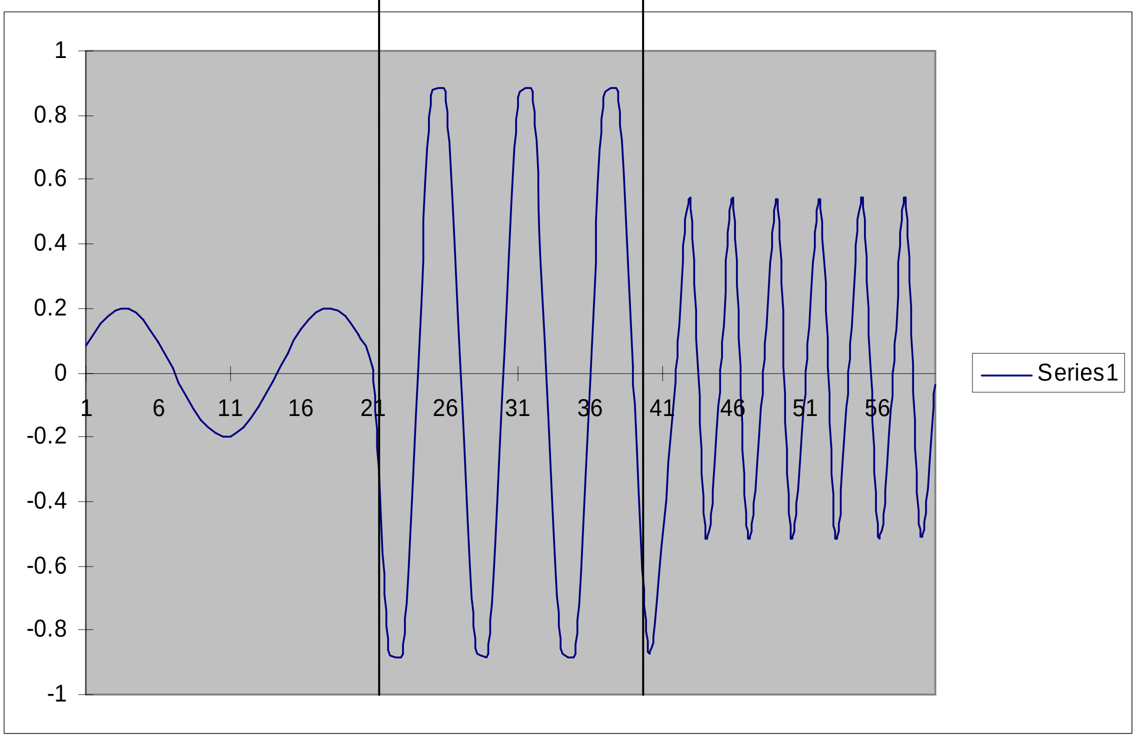
b) kick stimulus and damped sine wave



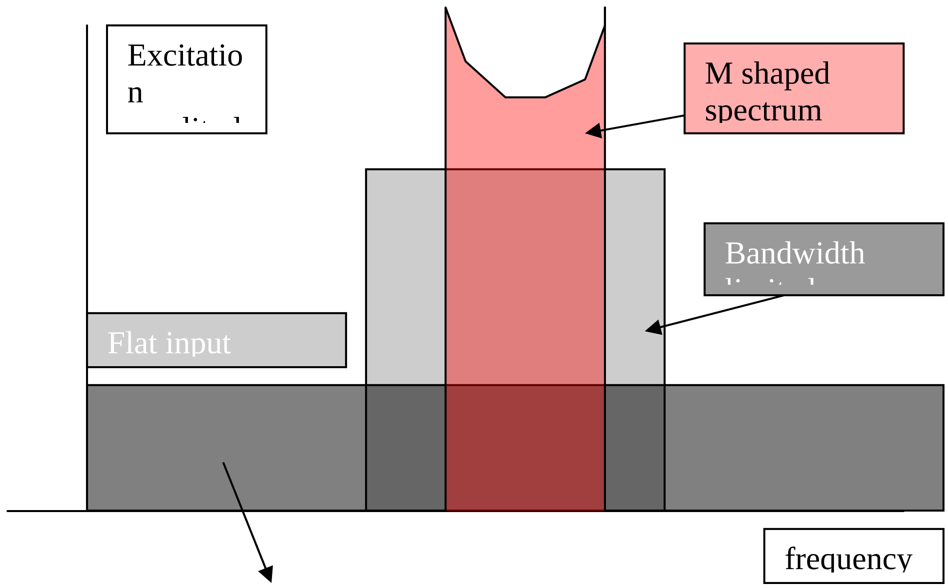


c) chirped beam excitation;
the excitation and beam response is shown for 3 different steps of the chirp

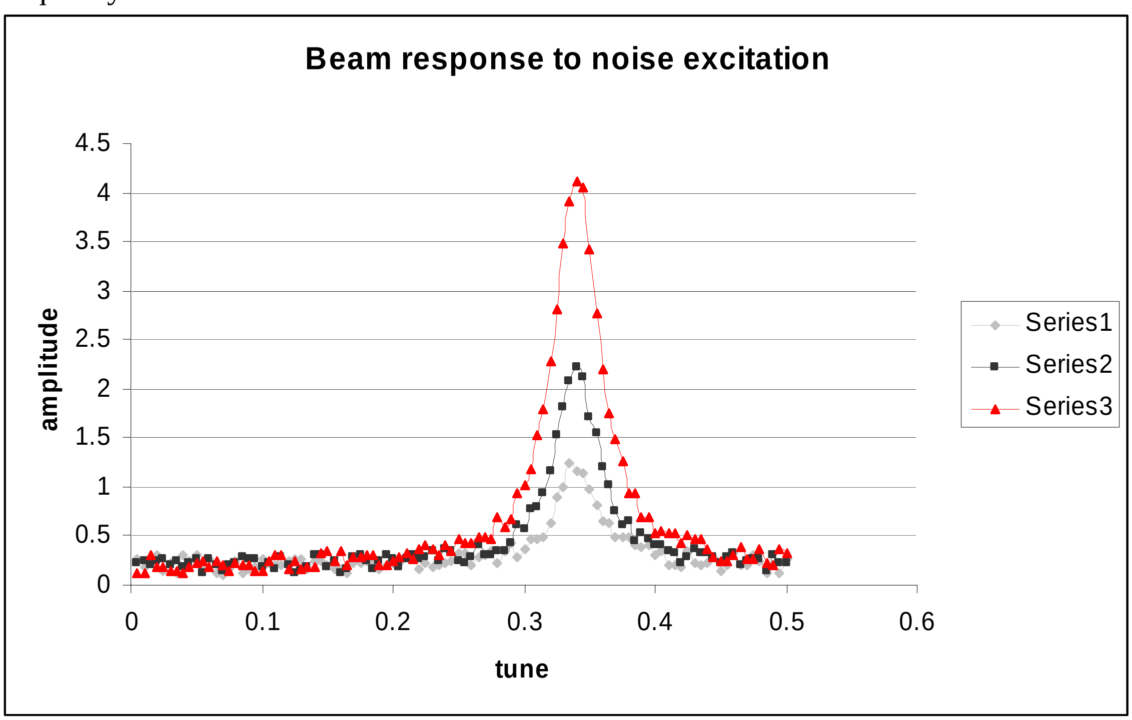




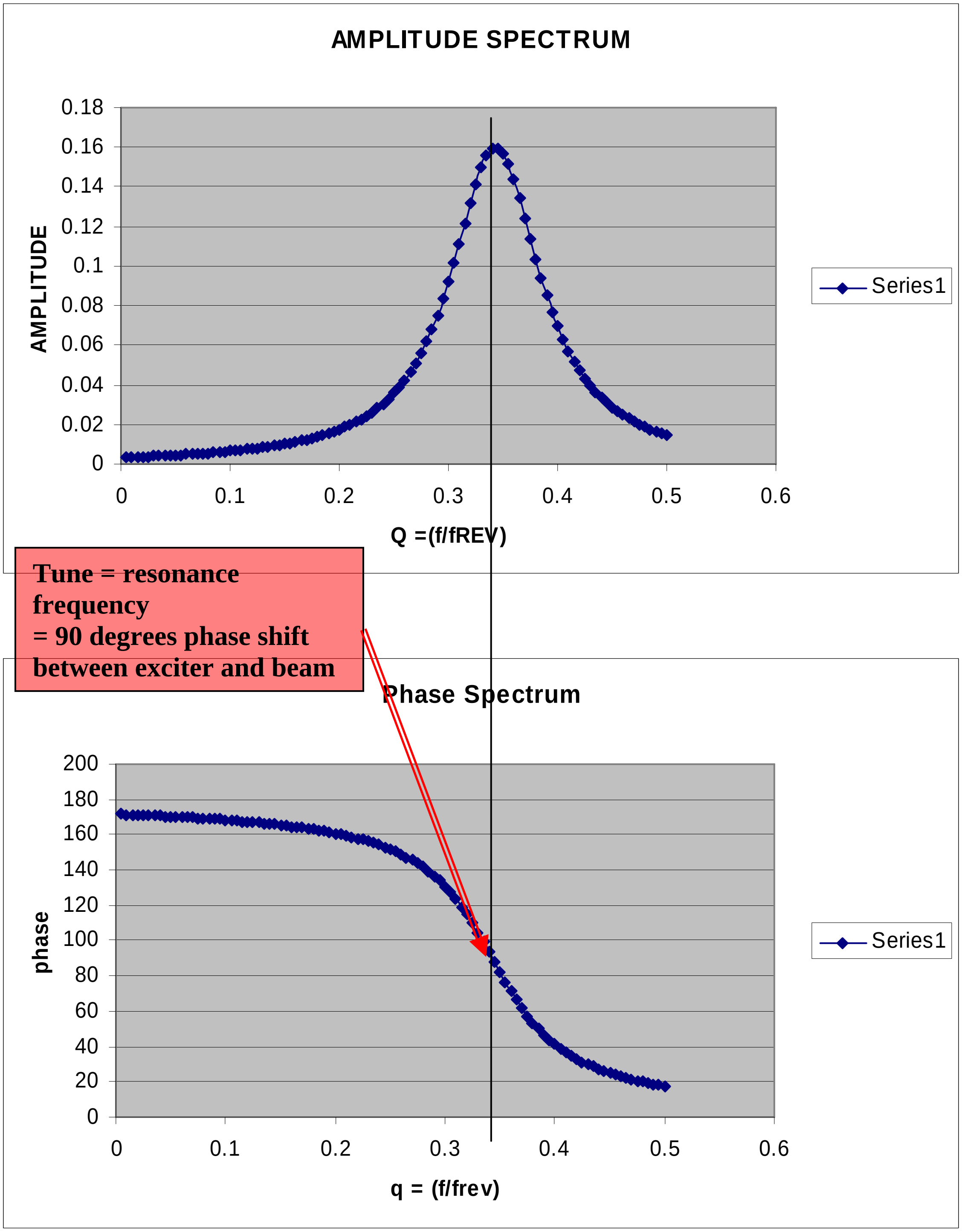
Solutions 2



In case of a noise excitation with reduced bandwidth one concentrates the excitation energy better to the eigenfrequency of the beam, i.e with the same excitation power one gets a larger beam response. Special shaped noises (I.e. "**M shapes**")have been used to get the best signal to noise ratio for all parts of the beam transfer function In case the excitation band gets very narrow (pure sinewave) one measures a single point in the beam transfer function. This is the first step towards a PLL; one has just to make sure, that the frequency is on the resonance.



Answer to question 3:



Answer to question 4:

Any non-linear circuit will create spectral components, which contain the sum and difference frequencies of the two input signals. The most popular phase detector is a simple analog multiplier:

It produces:
A sin (wt) * B sin (wt+Φ) =

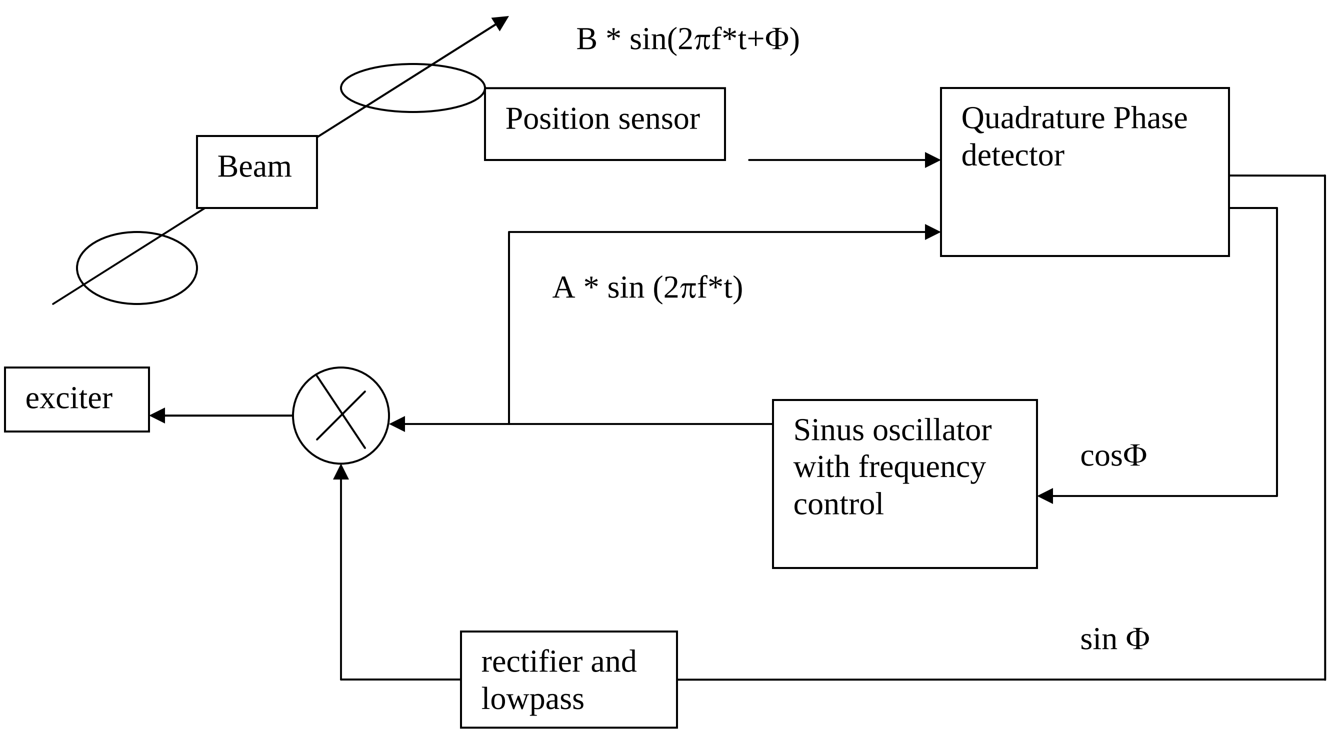
½ *A*B* (sin(wt + wt +Φ)) - cos(wt-wt-Φ))

= **const * cos (Φ) + const* sin (2wt +Φ)**

This signal will be sent through a low pass filter, which has a cut-off frequency well below the resonance frequency (10…1000 times lower). What remains is a signal:

const * cos (Φ)

Answer to question 5:



Answer to question 6:

The upper right corner shows the beam exciter and BPM.
The other gear serves to transpose the excitation signal to a carrier frequency of 245 MHz and to demodulate the observed oscillation.
This way a standard EM coupler can be used to excite the beam and a resonant BPM at 245 Mhz for the high sensitivity observation.
The described flowchart is realized as c-code.

No closed loop on beam excitation control is implemented at RHIC.

Answer to question 7:

One measures the local value of the beta function.
principle: a (small) strength variation Dk within a quadrupole induces a tune variation Dq :

- **Dq = Dk/4π ∫Quad b(s) ds**
- **< b > = (4π Dq /LDk) (1+e(Dq))**

$$\frac{\delta\langle\beta\rangle}{\langle\beta\rangle} = \left[2\left(\frac{\delta k}{\Delta k}\right)^2 + 2\left(\frac{\delta q}{\Delta q}\right)^2 + \left(\frac{\delta L}{L}\right)^2\right]^{1/2}$$

If one wants 1% error on the beta-value, one needs a tune resolution which is 1.4 *10-2
Of the induced tune change, which itself is of the order of 10`-4 if modulating a single magnet in a big machine.
This demands a tune resolution of 10-6, which is 10-3 of the width of the betatron line!
Quite a challenge….