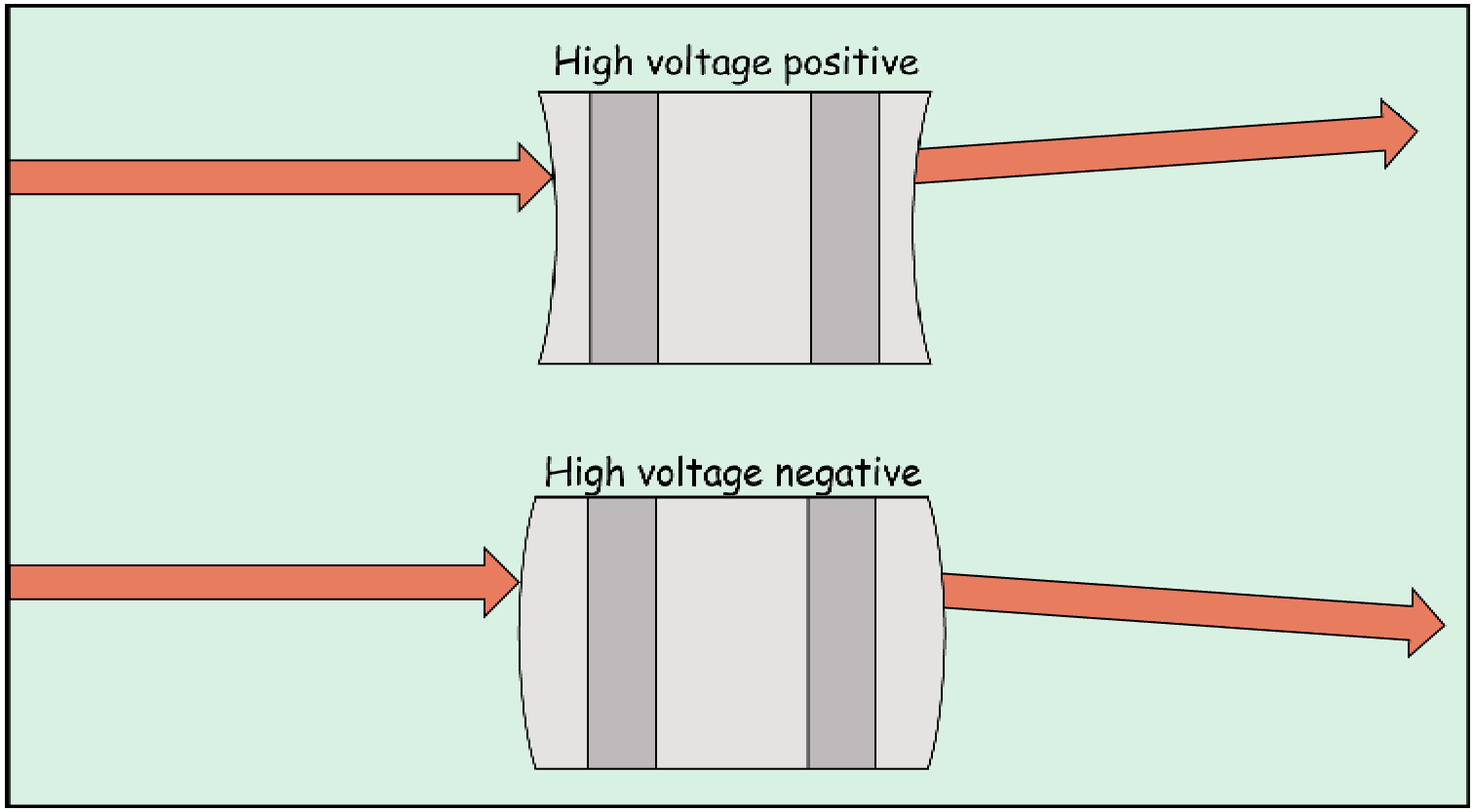
Short Tutorial on Causes of Position Differences…

…and what we can do about them

(most slides stolen from Cates PAVI '04 talk)

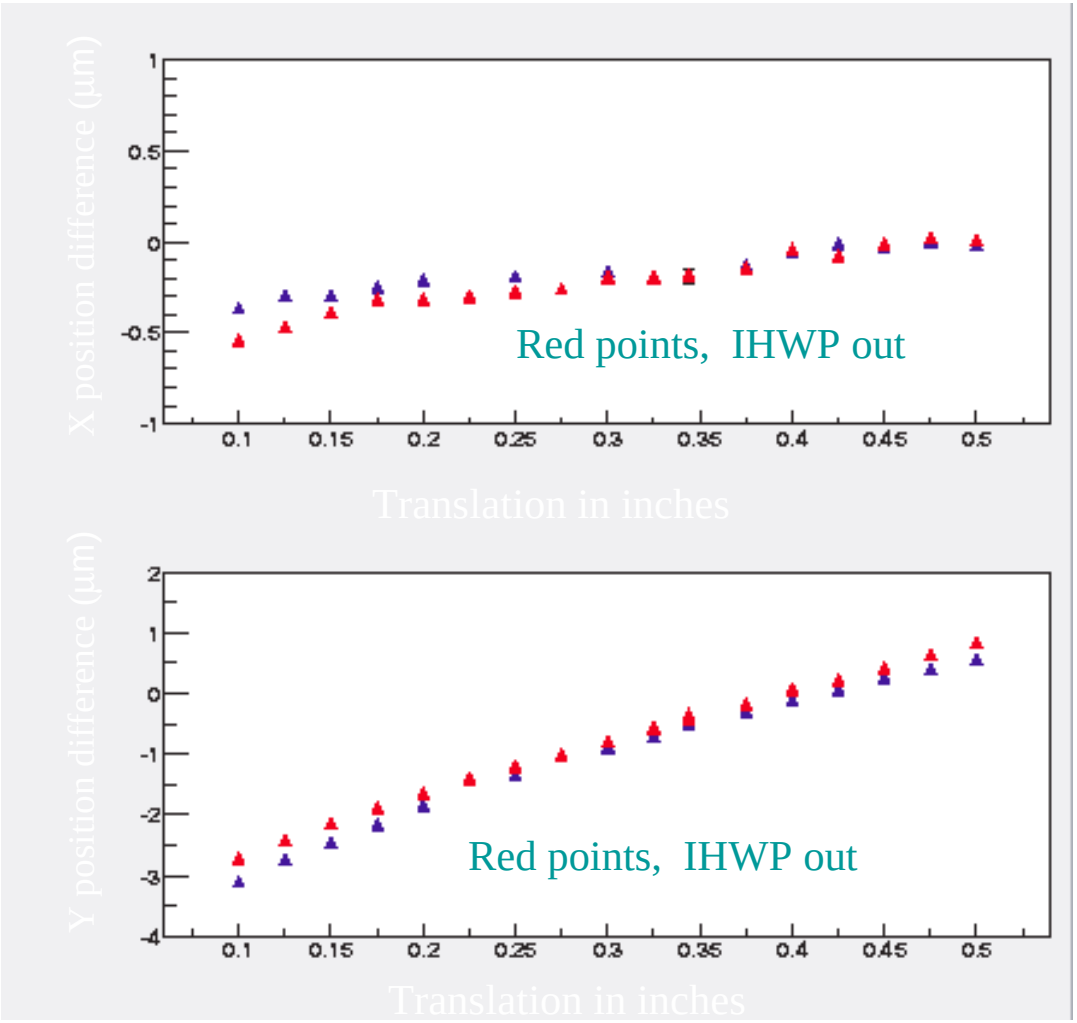
Steering effects

- Pockels cells can act like voltage controlled lenses.
- If beam is off-center, it can be steered.
- Helicity correlated position differences result.



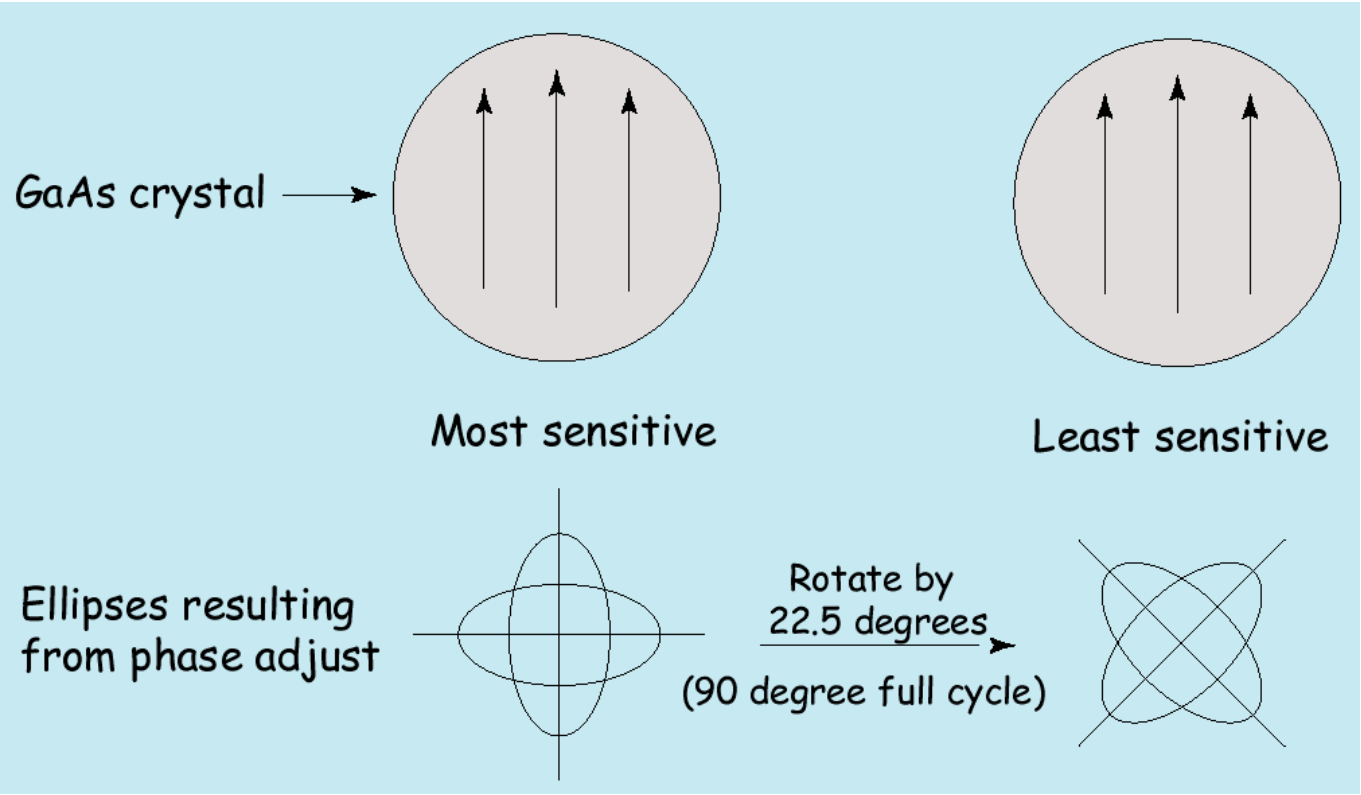
Measuring and minimizing steering

- Steering is generally minimized by going through the center of the cell.
- Steering **DOES NOT CHANGE SIGN** (that's good) when an insertable half-wave plate (IHWP) is put into the beam.
- Steering effects thus cancel to first order by using an IHWP.



The photocathode is often the dominant analyzing power, determining the PITA slope

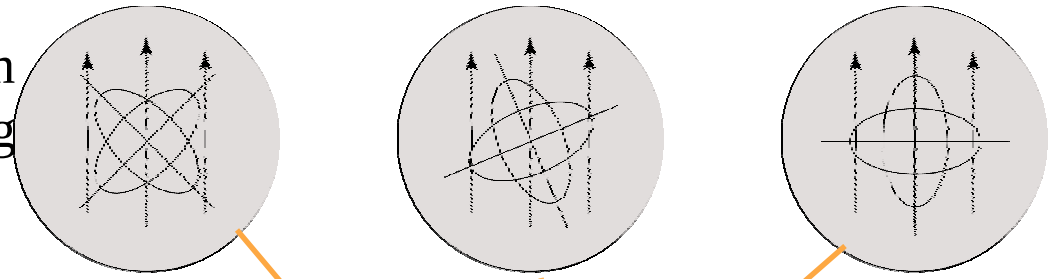
In a Strained GaAs crystal, there is a preferred axis.
Quantum Efficiency is higher for light that is polarized along that axis



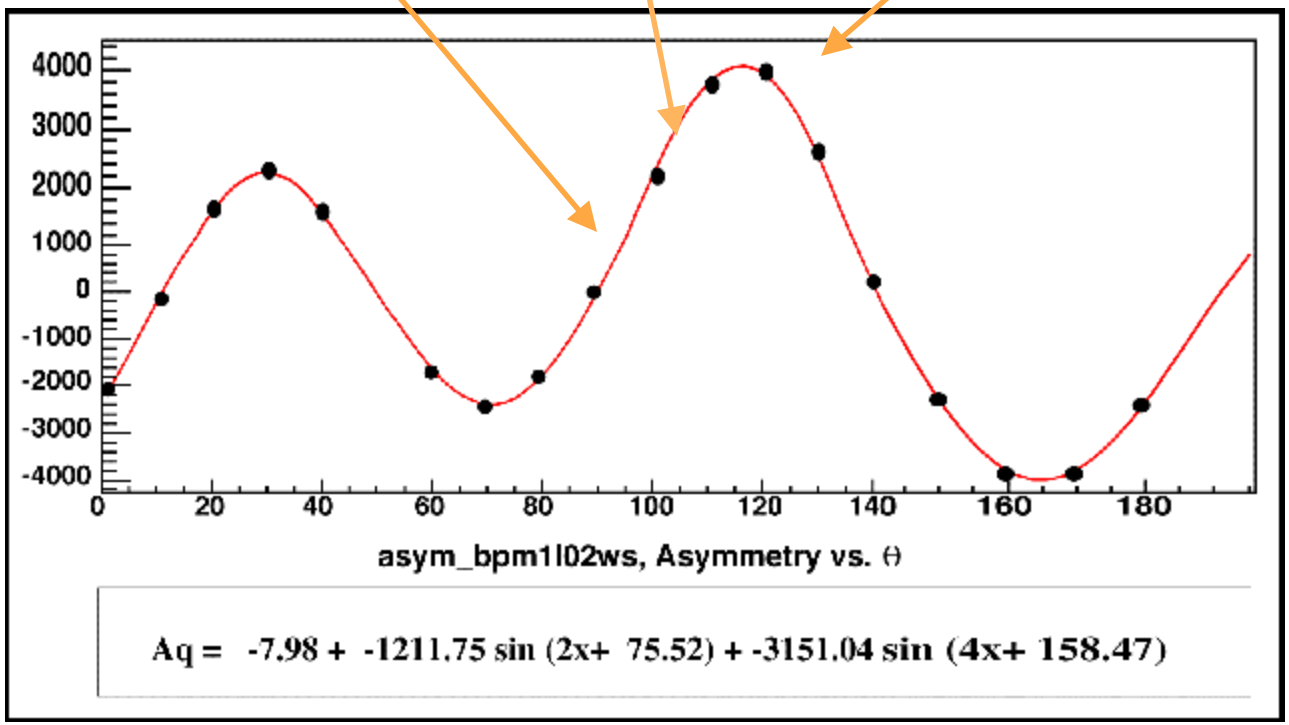
It is desirable to have a means for orienting your ellipses

Charge asymmetries while rotating the half-wave plate

minimum analyzing power



maximum analyzing power



Its easier to set the Pockels cell voltages for zero asymmetry if the PITA slope or analyzing power is fairly small.

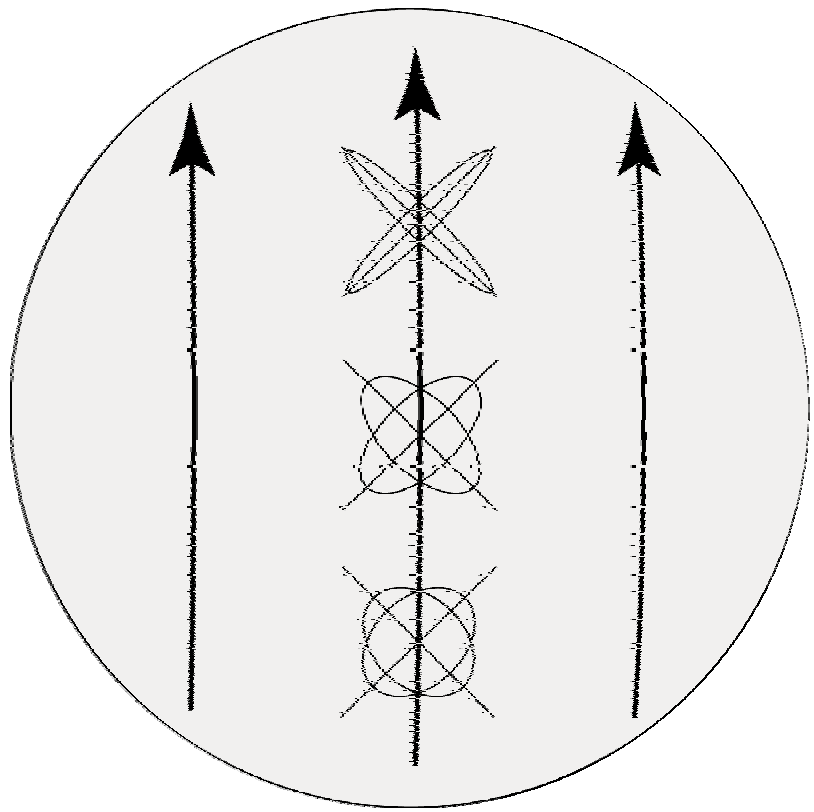
What happens if there are phase gradients across the laser beam?

The presence of a gradient in the phase introduced by the Pockels cell or, for instance, vacuum windows will result in varying linear polarization across the photocathode.

Large Δ

Medium Δ

Small Δ

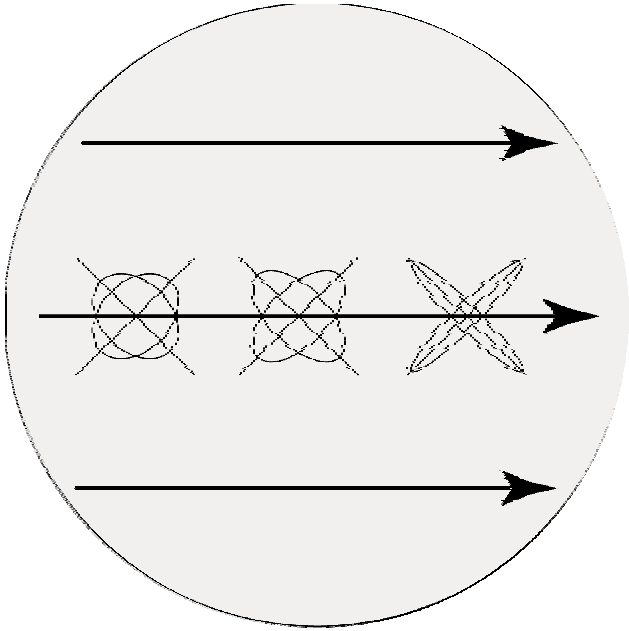


Big charge asymmetry

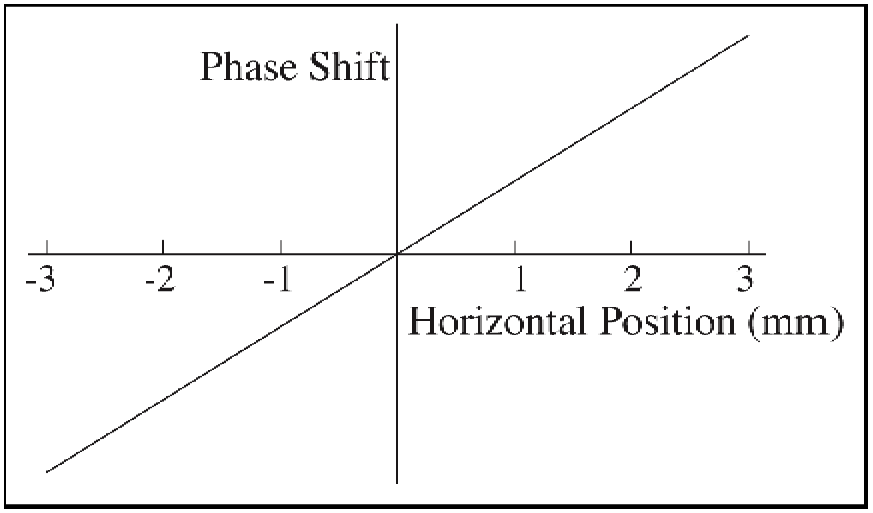
Medium charge asymmetry

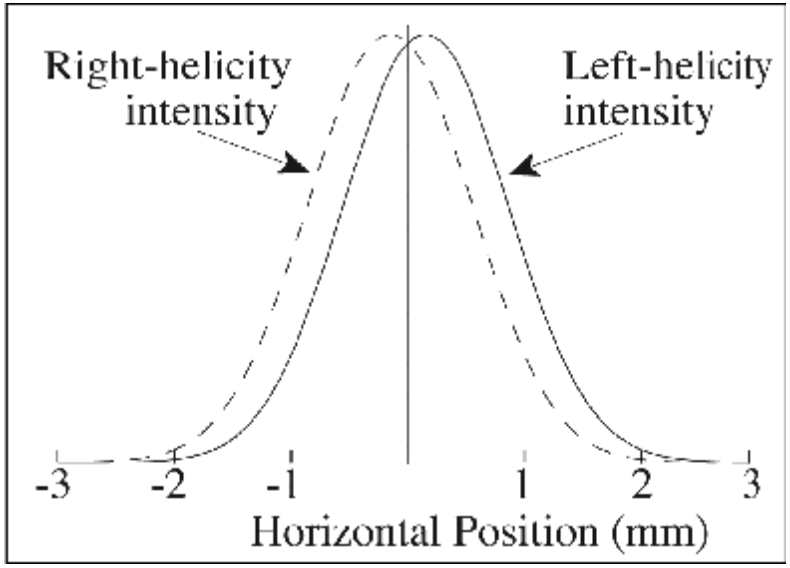
Small charge asymmetry

Phase gradients cause position differences



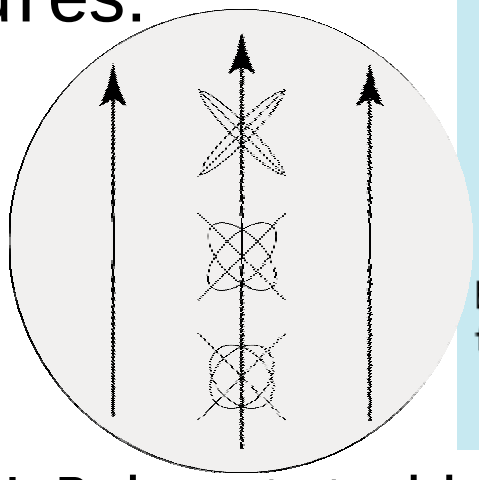
Gradient in phase shift leads to gradient in charge asymmetry which leads to beam profiles whose centroids shift position with helicity.

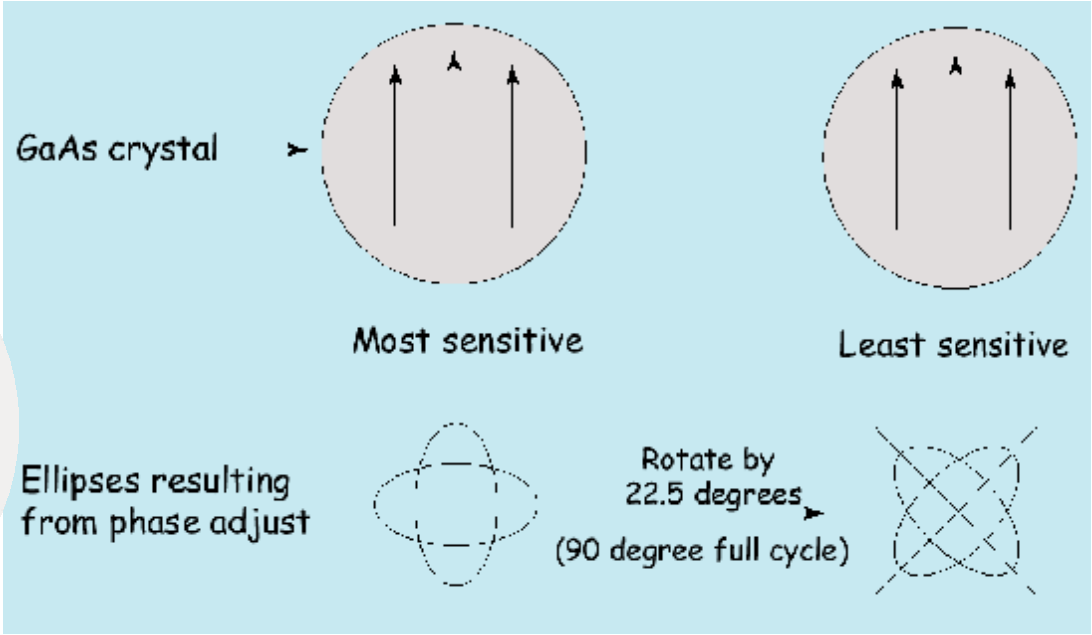




RHWP and Polarization Gradients

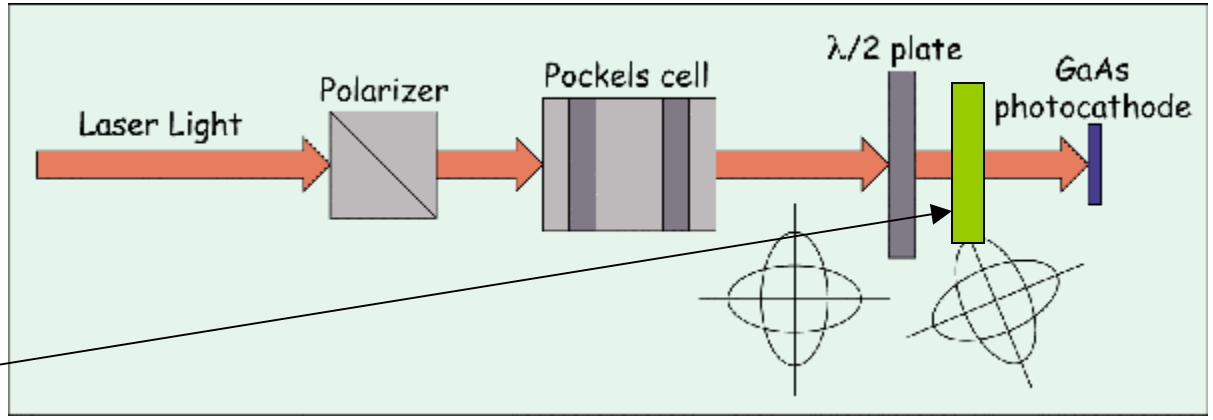
Combine these two Pictures:





Clearly, if L.P. is rotated by RHWP, the position differences due to the gradient with modulate – "4θ term"

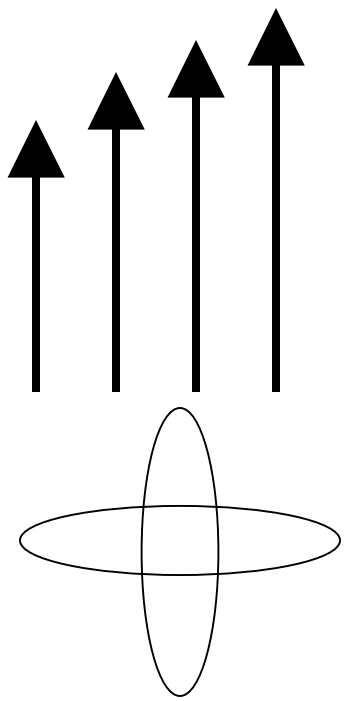
But not all L.P. rotates:



Vacuum Window

Cathode Gradients

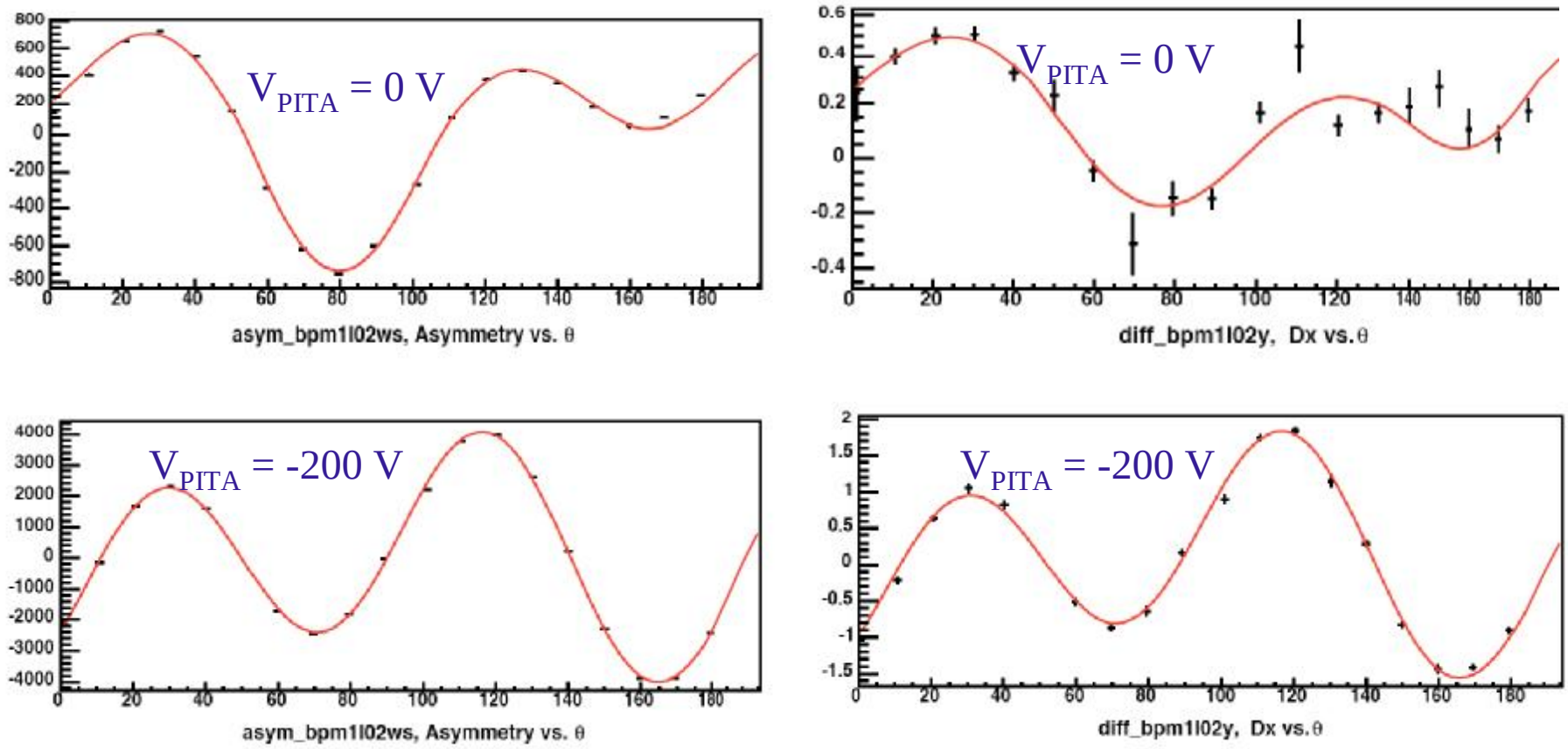
- What if DoLP is constant over the beam spot… but analyzing power isn't?
  - Position differences are created through an intensity gradient, just like for polarization gradients
- Orientation still matters
  - 4θ term in RHWP
- DoLP matters
  - This isn't true for polarization gradients
  - Zeroing the Analyzing Power with the RHWP doesn't necessarily zero A_Q… and doesn't necessarily zero DoLP!
  - Zeroing the Charge
  - Changing the PITA setpoint changes DoLP… so use the Pockels cell to zero DoLP on cathode.



Finding a good operating point

Charge asymmetries

Position differences



Sources of Position Differences

Steering/Lensing	•Insensitive to polarization •Zeros at "geometric center"	•Insensitive to RHWP, IHWP •Align Cell to geometric center
Pockels Cell (upstream) Birefringence Grad	•Scales with effective analyzing power (PITA slope) •Changes sign with polarization	•Modulates with PITA slope (RHWP) •Flips with IHWP
Vacuum Window (downstream) Birefringence Grad	•Unaffected by orientation of incident L.P. •Changes sign with polarization	•Insensitive to RHWP •Flips with IHWP
Cathode Analyzing Power Gradients	•Proportional to DoLP •Changes sign with polarization	•DoLP from P.Cell modulates with RHWP •DoLP from V.W. is constant with RHWP •Zero A_Q with PITA ! •Flips with IHWP

Configuration procedure

- Move to a small effective analyzing power (PITA slope) using RHWP.
  - How small? Large enough to zero A_Q with reasonable PITA offset, and no larger.
  - Verify that position differences are reduced near this zero crossing.
  - Why not zero A_Q with RHWP? Because a possibly large analyzing power will amplify P.C. birefringence gradients.
- Zero A_Q using PITA offset
  - This should kill remaining position difference
  - Note: IA cell does no good for cathode gradient effect
- Complications
  - Vacuum window birefringence gradients aren't touched
  - Measurement precision is limited
  - Measurements are difficult to interpret as the propagate through injector

What did we learn?

…and what do we want to do about it?

Lessons Learned

- Significant polarization gradient seen on laser table, not consistent with anything we model.

- Clear evidence of cathode gradients, birefringence gradients, and steering (later controlled with work on laser table). Position differences off cathode largely understood.

- Interaction of high-current beams on cathode
  - Is it possible: “circuit” current limit (not cathode effect)?

- Problems in simultaneously treating two high-intensity laser beams.
  - Can we improve this with improved beam combination technique?

Looking to next year

How to build on our success…

- Time spent in tunnel was productive and crucial. We should repeat what we did, possibly with some improvements.

- Stability is precious, and rare. How can we become more stable (injector orbit and phase, beam interaction on cathode, cathode properties)?

- If stable but matching the 2004 numbers, we may want position feedback to finish the job (take 10nm a 2nm).

The people to get it done

- Responsive, flexible, dedicated, positive EGG got the job done
  - Support during configuration
  - Tending the superlattice
  - Laser instability
  - Maintaining beam intensity AND dynamic range in feedback systems
  - Vertical polarization

- How can we make their job easier?
  - Scheduled configuration time (may happen for HAPPEX)
  - Only 1 high-current run at a time (may happen for HAPPEX-H)
  - Prepare as much as possible in advance of the run (ITS study, beam studies…)

Wish List

- SUPERLATTICE!
- Spare Pockels Cells?
- Pockels cell translation stage micromotor
- Continued ITS Laser room operations
  - Improved mock up of tunnel configuration, to try to understand polarization gradient
  - Understand effect of beam spot size at cell and at cathode
  - Improve point-to-point imaging of cell to cathode
- Study of multiple beam interaction on cathode?