Photocathodes for Polarized Beams

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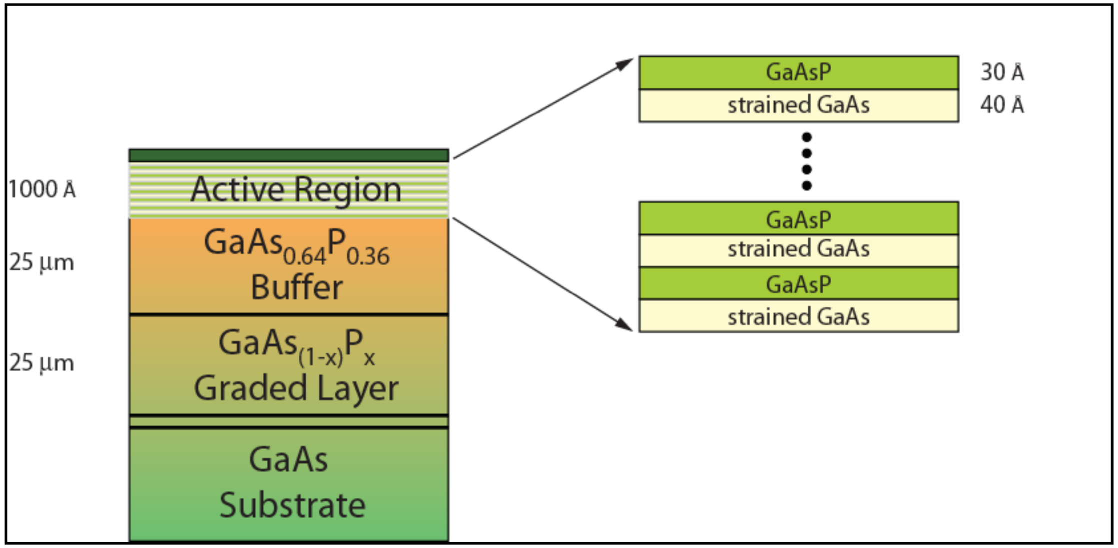
SLAC

ILC e- source KOM, September 24-25, 2007

Photocathodes

Baseline design: strained layer superlattice GaAs/GaAsP
- Polarization ~ 85 - 90 % ,QE 1% maximum, 0.3-0.5% routinely



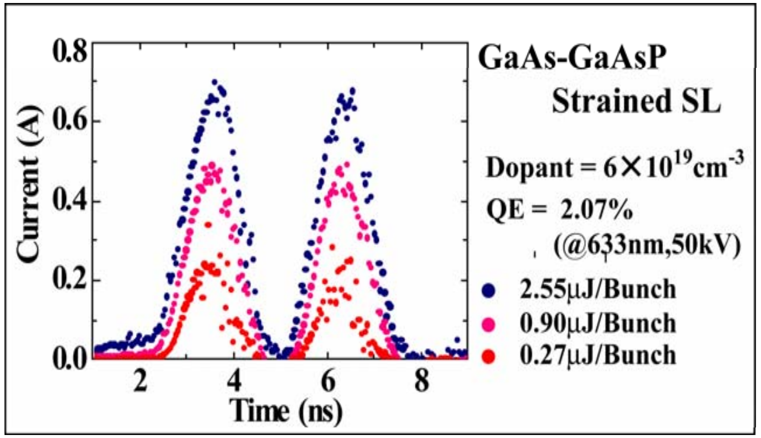
High gradient p-doping increases QE and reduces surface charge limit:

$$5 \times 10^{19}\ cm^{-3} \rightarrow 5 \times 10^{17}\ cm^{-3}$$

Surface Charge Limit

Surface charge limit has not been studied under the ILC conditions

Nagoya



p-p : 2.8ns,
bunch-width : 0.7ns
Charge: 1nC/bunch

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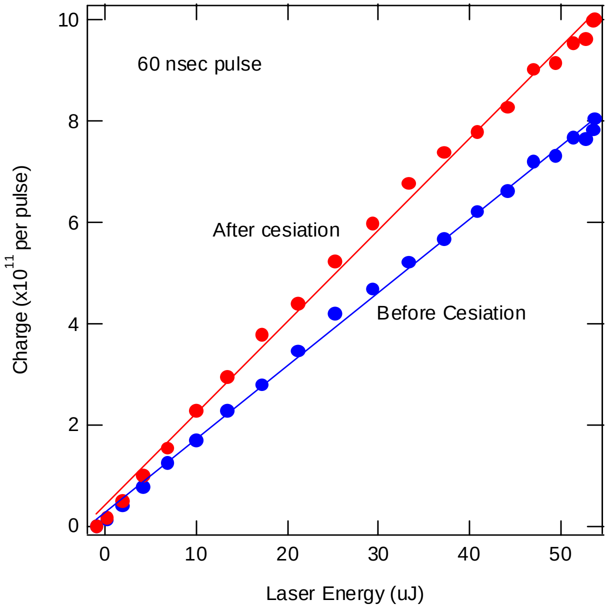
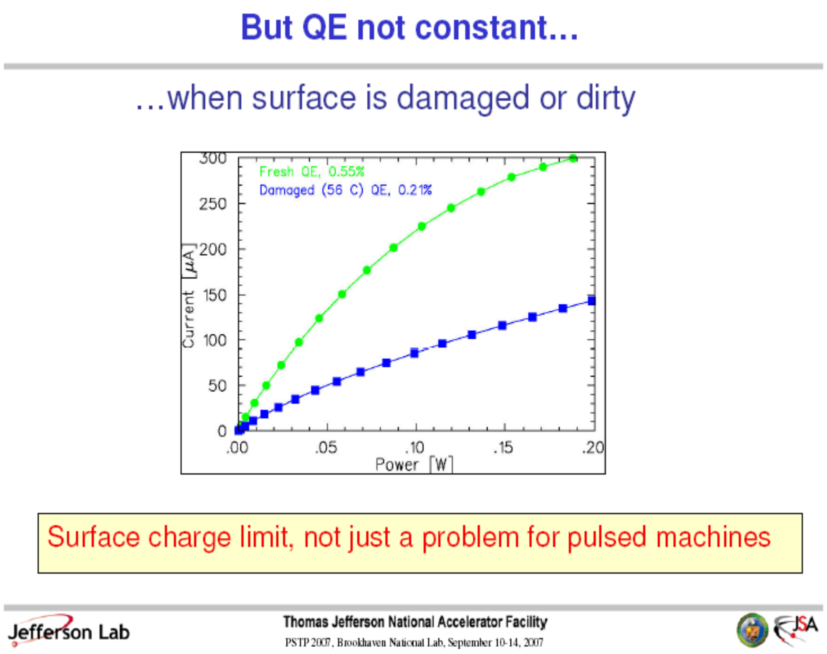


1×10^{12} e- in 60 ns
$\rightarrow 4.5\times10^{12}$ e- in 270 ns
($\times$3 NLC train charge)

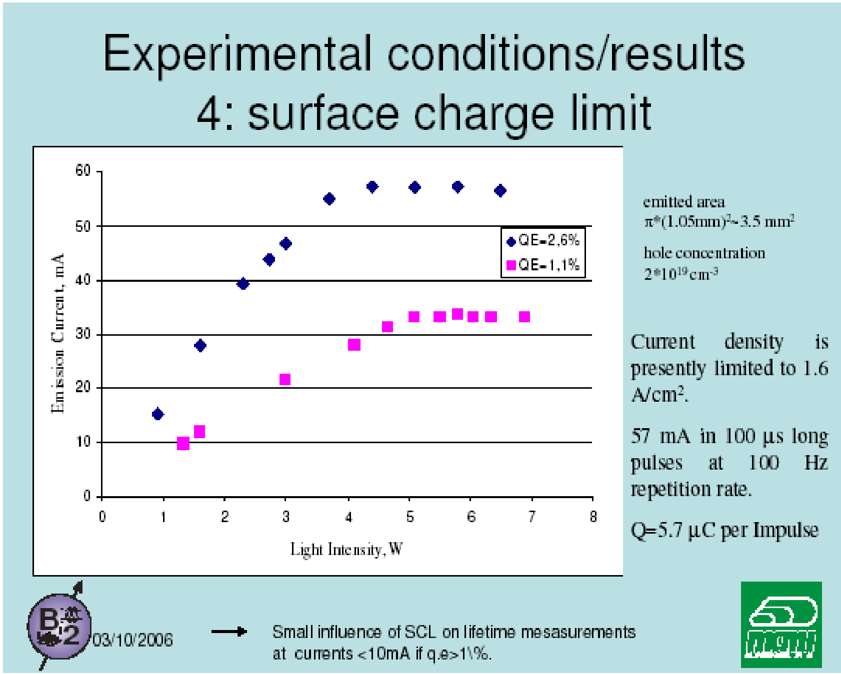
No charge limit in < 300 ns.

Surface Charge Limit seen in CW machines

Poelker (PSTP07)

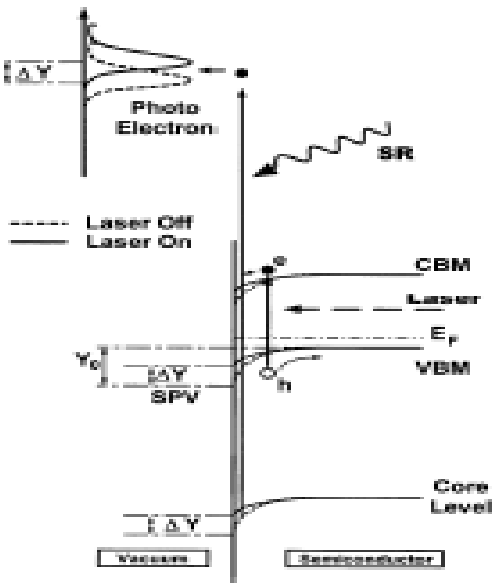


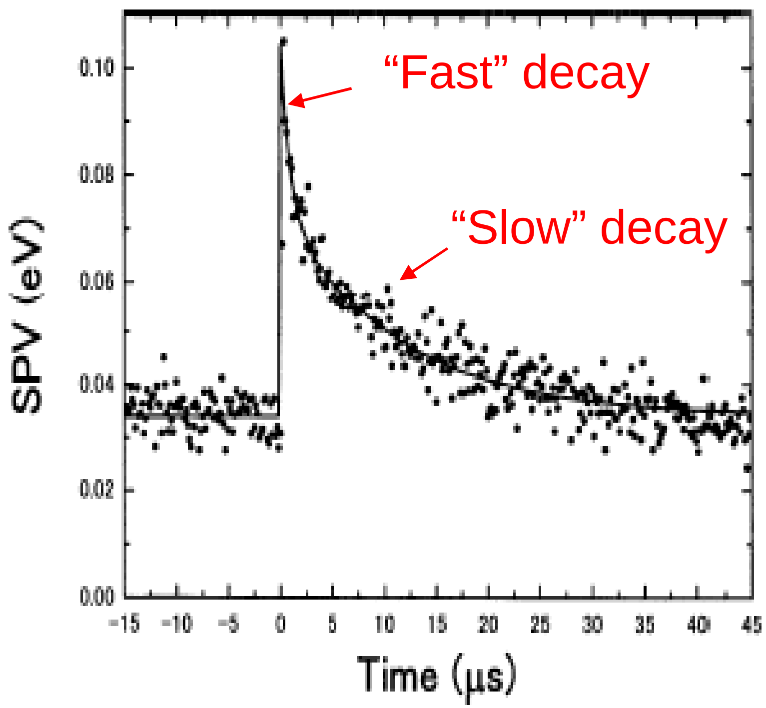
Aulenbacher (Spin06)



“Fast” and “Slow” Photovoltage Decay Time

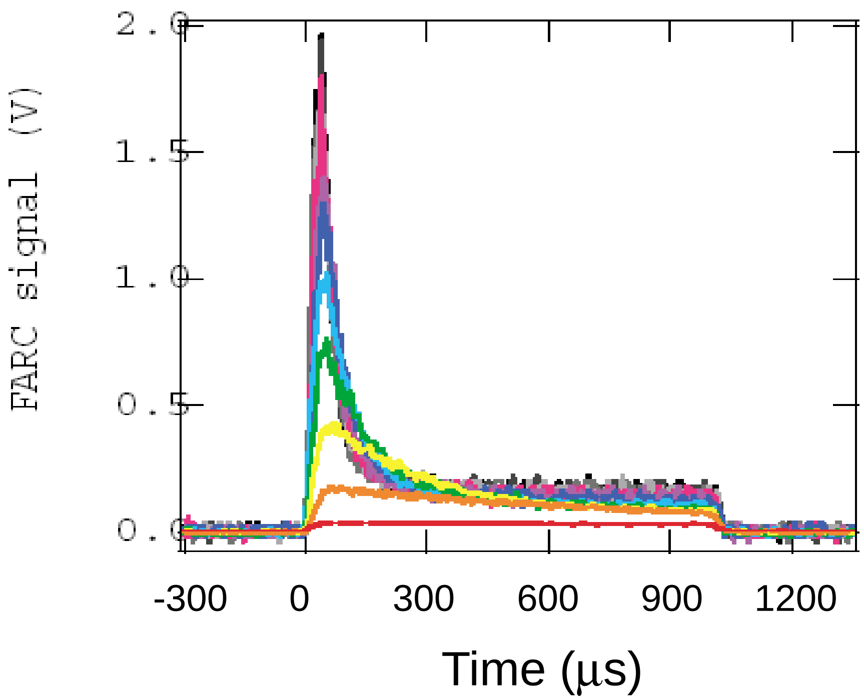
S. Tanaka et al. Surface Review and Letters, 9, 1297 (2002)





ILC Train Extraction

- Need to demonstrate ILC train extraction as soon as possible.
- ILC laser development should be highest priority.



ILC train may look like this.

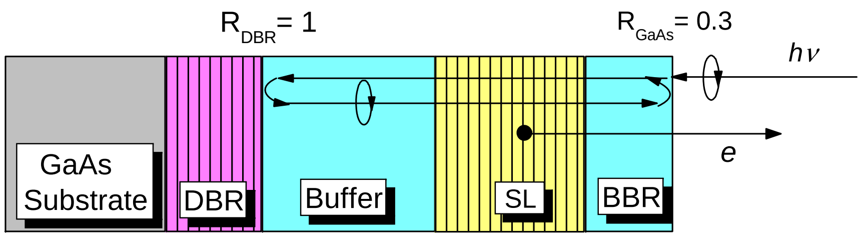
Lower heat-cleaning temperature

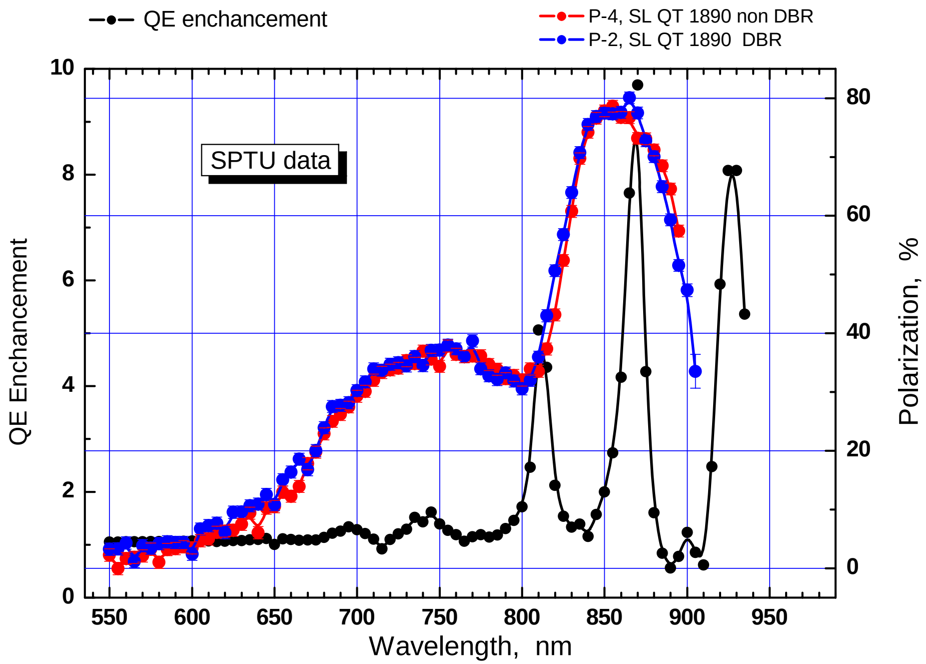
- Cathode needs high temperature (~600° C) heat-cleaning to achieve high QE.
  - – Dopant diffusion → surface charge limit
    - Try carbon doping
  - – Surface damage/surface states → surface charge limit
- Lower heat-cleaning temperature to ~450° C and achieve high QE
  - – Atomic hydrogen cleaning

Resonant enhancement of QE

Gerchikov (PSTP07)

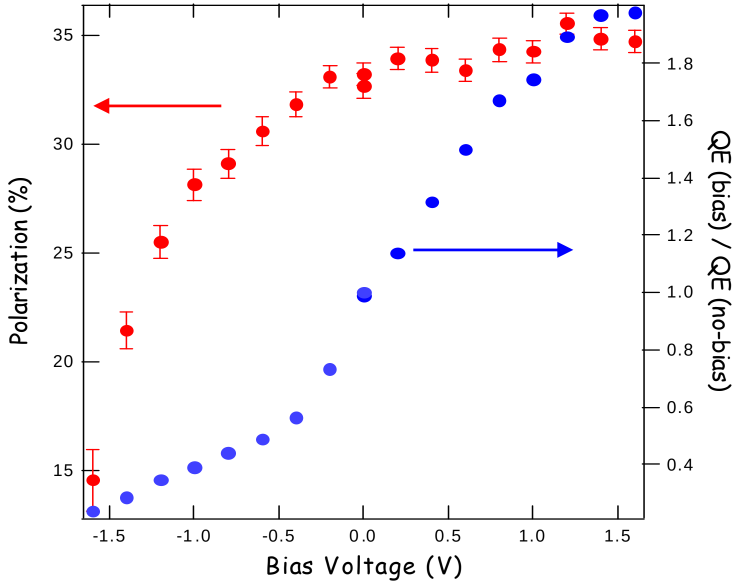
- ILC laser may not have enough energy.
  - 5 µJ/pulse is tough.
- DBR was first introduced by Nagoya group.
- ×10 QE enhancement has been achieved.
- Structure gets more complex, and matching pol max and QE max is not quite reproducible.

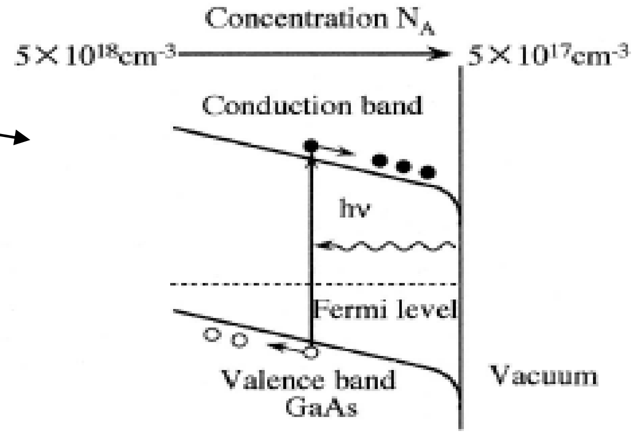




Bias enhancement of QE

- QE enhancement is possible when the cathode front surface is positively biased.
- Polarization increases as the electron drift time gets shorter.
- External bias
  - SBIR with Saxet Surface Science.
- Internal bias
  - Gradient doping
    - W. Zhen et al., JJAP 38, L41 (1999) (Photoluminescence study)
  - Gradient composition
    - SBIR Phase I with SVT



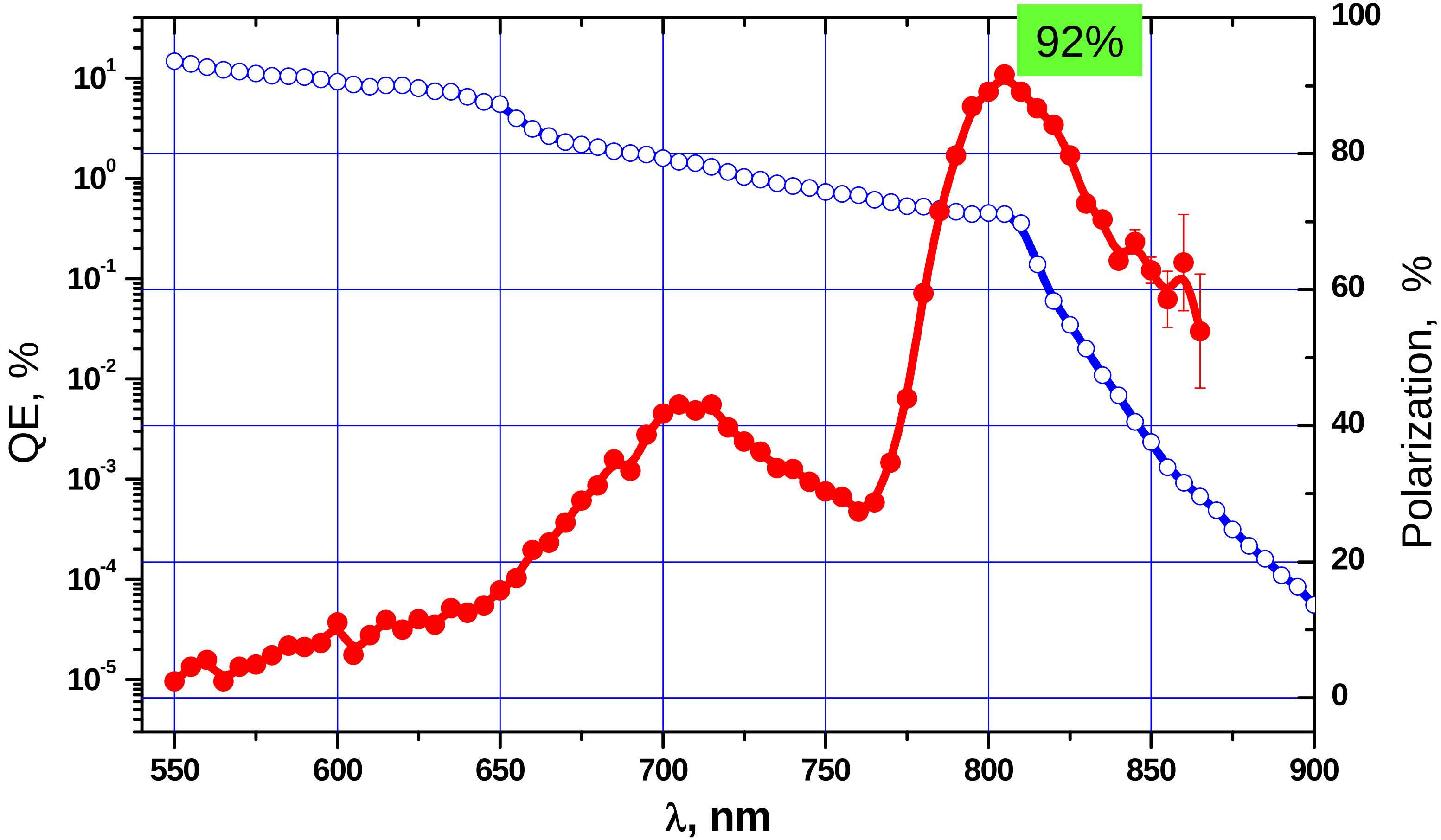


Polarization improvements

- GaAsP/GaAs strained superlattice
  - Superlattice parameter optimization
  - Doping profile optimization
- New structures
  - InAlGaAs/AlGaAs strained superlattice
    - In collaboration with St. Petersburg group.
  - AlGaAsSb/AlGaAs strained superlattice
    - SBIR Phase I with SVT Associates

SL $In_{0.155}Al_{0.2}Ga_{0.645}As$(5.1nm)/$Al_{0.36}Ga_{0.64}As$(2.3nm), 4 pairs

Mamaev (PSTP07)



Spectra of electron emission: Polarization P and Quantum Efficiency QE

Wafer growers

- SLC single-strained wafers
  - All grown at Spire/Bandwidth Semiconductors
  - Wafer quality varied, each wafer characterized, and good wafers selected.
- GaAsP/GaAs strained superlattice
  - Nagoya University
  - SVT Associates
- Need to find wafer grower
  - SVT Associates may not be in business for long time.
  - Find University group?
  - Photocathode wafers are not industry standard.
    - Takes time to optimize growth

Wafer Characterization

- What is grown is not always what is designed.
- Polarization and QE alone do not characterize the structure.
- Ability to characterize wafers is important.
  - Photoluminescence
  - X-ray diffraction
  - Surface analyses: XPS, EDX, SIMS