Recent Achievements in Solid State Detectors for Eye Safe Laser Ranging

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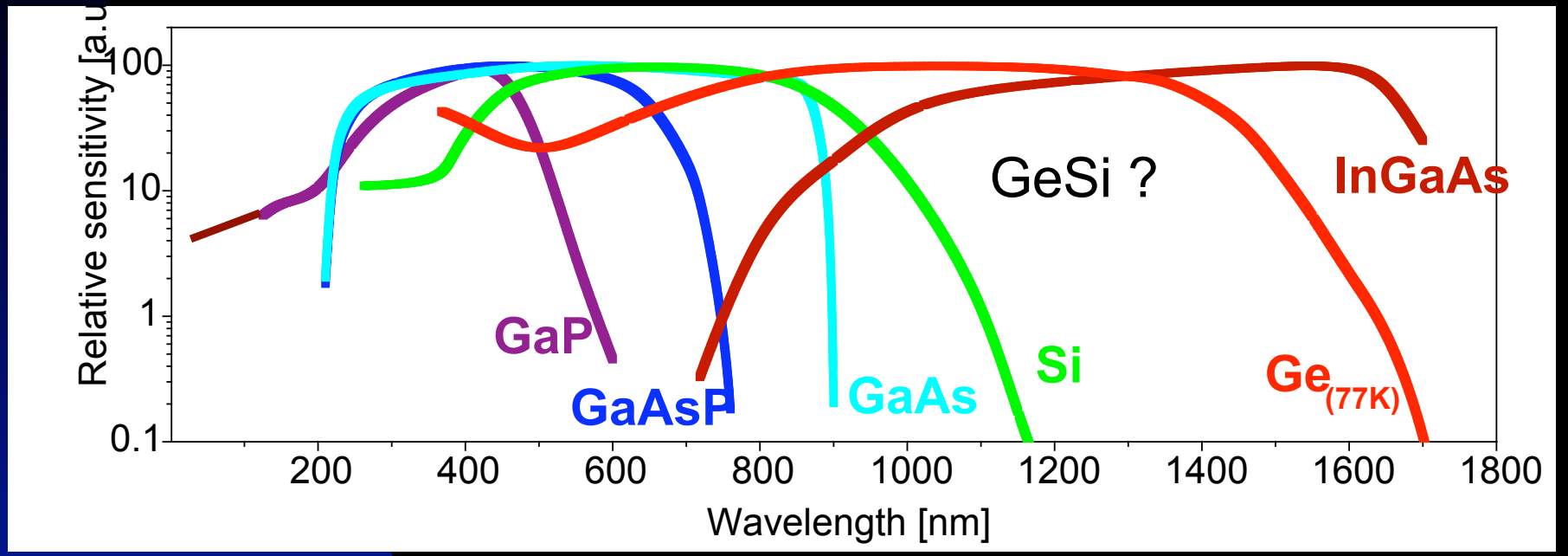
Goal

- Laser ranging at 1500 nm wavelength earnge
- Photon counting detector
- high quantum efficiency (QE > 10 %)
- low dark count rate (<< 1 MHz)
- high timing resolution (FWHM < 200 ps)
- fieldable

Single Photon Avalanche Diodes
Semiconductor materials



Laser wavelengths used for SLR / SPADs

Eye safe

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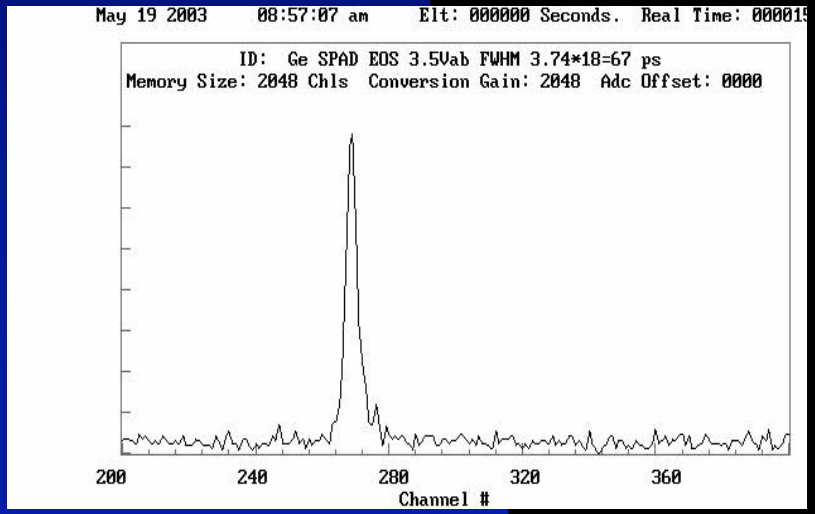
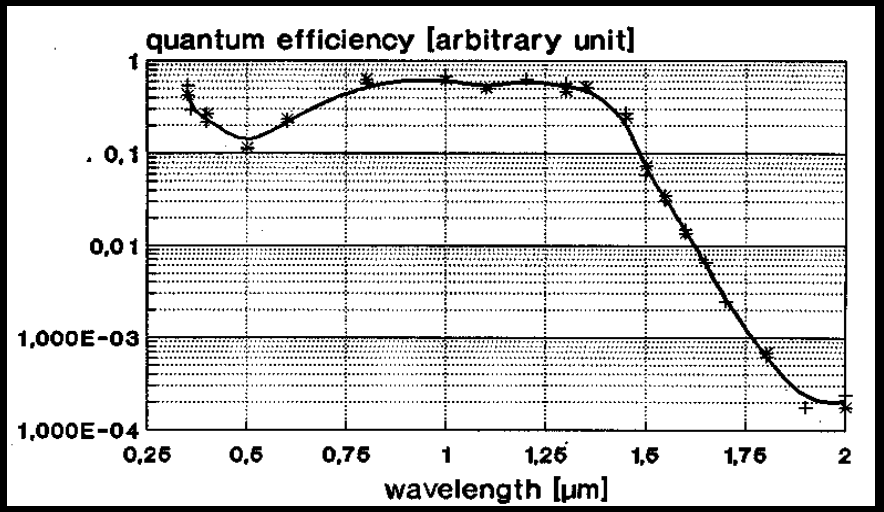
Germanium SPAD Detector Package

The first eye safe SLR in Tokyo, CRL & PESO & EOS, 1996

Ge SPAD, 100 um
compact liquid N_2 cryostat, 77 K
the electronics built in
timing resolution 25 ps rms
QE 2-5% @ 1540 nm
dark count >= 1 MHz





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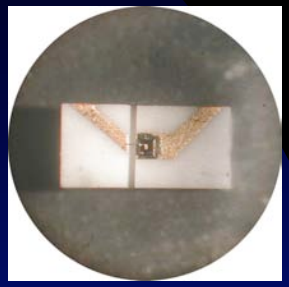
InGaAs Detectors for Photon Counting



- quantum efficiency > 10%
- operating temperatures 150-300 K

- high after pulsing effects
- high serial resistance =>
  low avalanche currents (<< 1mA)
- structure is difficult to manufacture,
  limited chips availability

InGaAs SPAD Detector Package
New active quenching and gating circuit

GOALs

- to minimize the charge flowing trough the APD
  to reduce after-pulsing and hence the dark counts
- to respond to APD small pulses

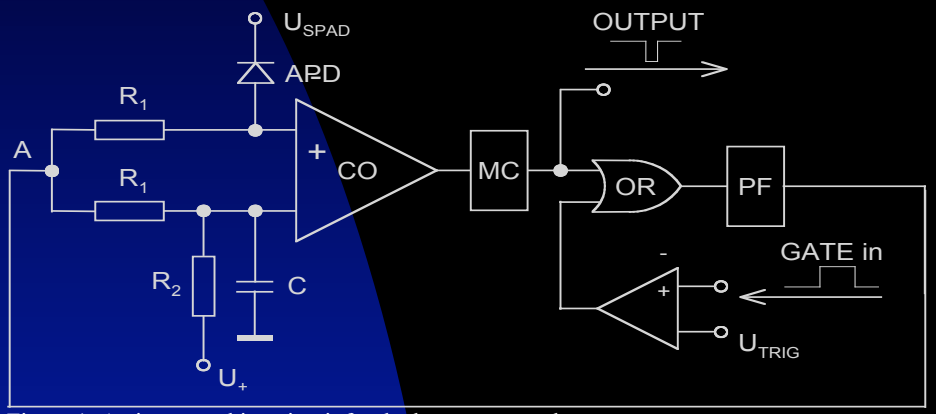
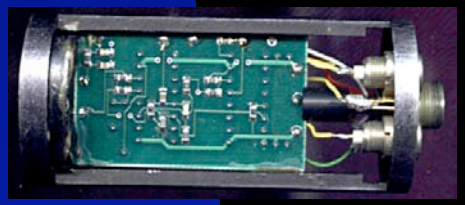


Figure 1: Active quenching circuit for the laser transponder

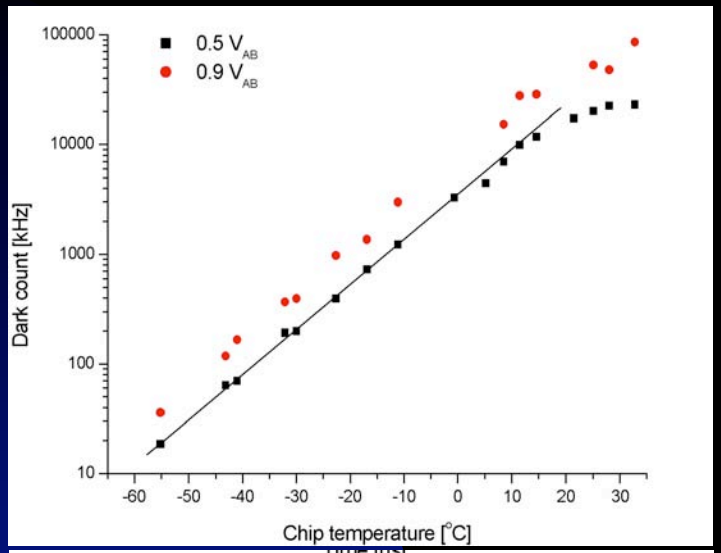
CO comparator
PF pulse forming
MC monostable
OR gate



responses to 10 mV / 1 ns pulses
loop delay 2.6 ns
ECL logic, SMD
=> 1 V above break max.

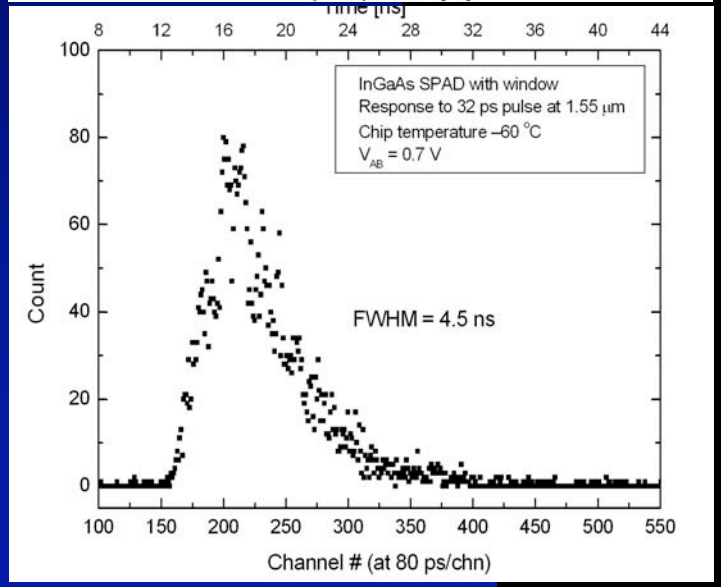
Low dark count rate InGaAs SPAD

Chip 80um in diameter, ECL active quenching, 1 kHz gate



Dark count rate

25 kHz @ -60°C



Timing resolution

FWHM	4.5 ns
rms	1.8 ns

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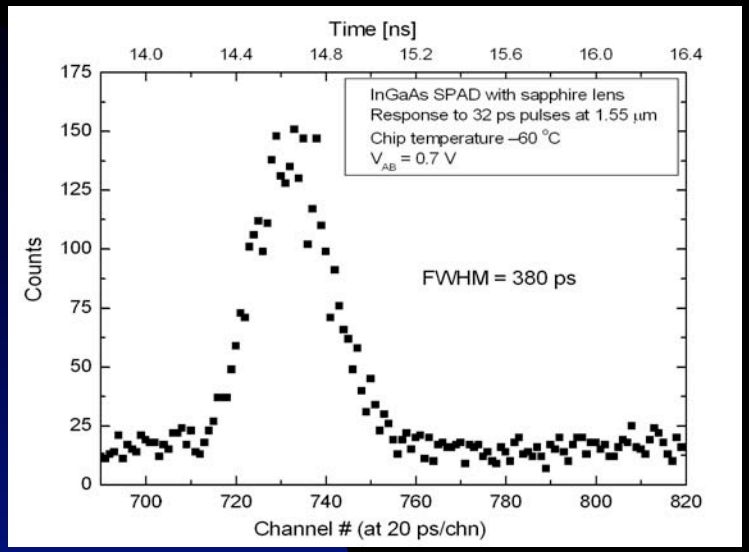
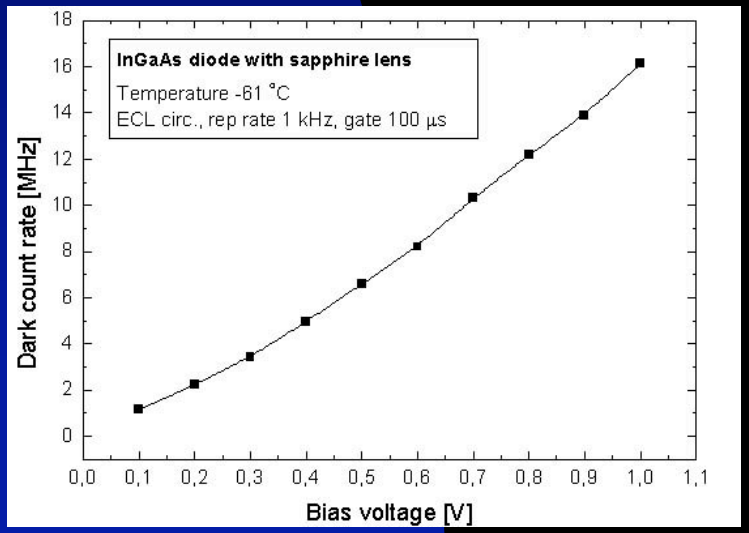
Fast response InGaAs SPAD



Timing resolution

FWHM 380 psec
rms 160 psec



Dark count rate
small drop with temperature

12 MHz @ -60°C

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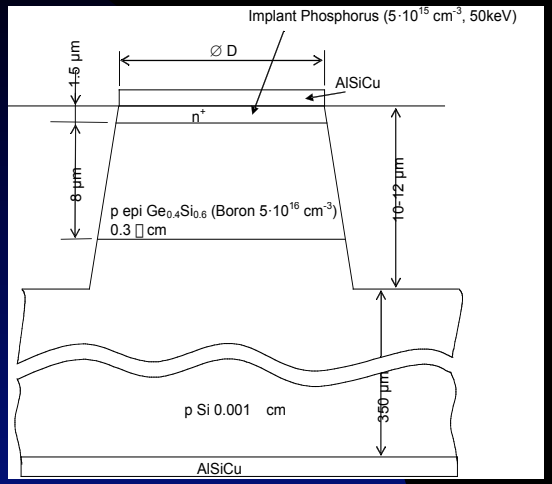
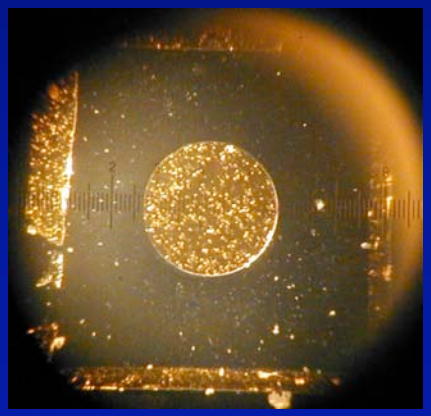
SPAD on $Ge_{04}Si_{06}$

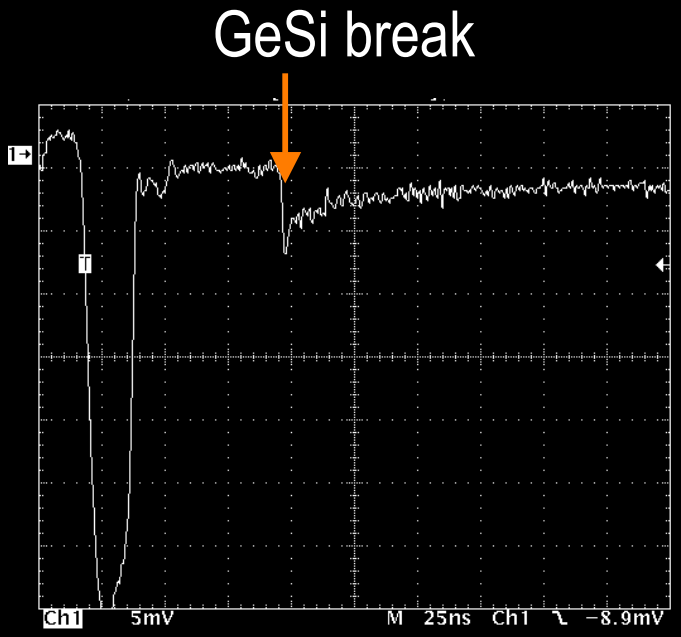
Development status quo



technology tests:
- GeSi layer 5 um on top of the Si
- diffusion, implantation, masking,..
- test purpose MESSA structure,



The first Geiger operation reported



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Conclusion

- PROGRESS
  in solid state photon counters for eye safe laser ranging

- new APD structures on InGaAs (30-80 um)
- new control circuits
- new cooling setups for 150 - 210 K

- ACHIEVED PARAMETRS (InGaAs @ 1550nm)

- quantum efficiency 13 %
- dark count 25 kHz @ -60 C
- timing resolution 160 psec
- however, the last two not at the same time

- „long way “ to operational GeSi detectors

Available Detectors Summary
Status Quo 2004

- Si — 20 years
  - compact package, 0.25 - 1.1 um, ps timing,
  - gated, not-gated operation
  - 20 .. 200 um, TE cooling, low noise,
  - photon number estimate
  - space qualified
- GaP
  - room temperature, X .. 0.8 um
  - 300 um, ps timing
- Ge — 10 years
  - 77 K , 0.25..1.6 um
  - 100 um, 1 MHz dark, gated, ps timing,
- InGaAs
  - 150..210 K, wavelength 1…1.8 um
  - 30 - 80 um diamater
    - ns timing, dark < 30 kHz
    - ps timing, dark ~ 10 MHz

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