RECENT ACHIEVEMENTS IN DETECTORS FOR EYE SAFE LASER RANGING

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Abstract

We are reporting on the latest results in the research and development of the solid state proton counters suitable for detecting individual photons in the near infrared wavelength region. The separate absorption and multiplication layer avalanche photodiode based on an InGaAs are one of the most promising candidates for the solid state photon counter for the eye safe laser ranging. Using the laboratory sample of InGaAs structure we have achieved the dark count rate as low as 30 kHz at modest temperature –60 C. The detector active area is 80 microns in diameter, its timing resolution of the detector is 1.8 nsec.
Recent Achievements in Detector for Eye Safe Laser Ranging

**Goal**

- Laser ranging at 1500 nm wavelength range
- 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**

Relative sensitivity [a.u.] vs. Wavelength [nm]

Laser wavelengths used for SLR / SPADs

Eye safe
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

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 through 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

ECL logic, SMD

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

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
Fast response InGaAs SPAD

Timing resolution

- FWHM: 380 psec
- rms: 160 psec

Dark count rate

- small drop with temperature
- 12 MHz @ -60°C

SPAD on Ge$_{0.4}$Si$_{0.6}$

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
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 PARAMETERS (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
  - 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
  - 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 diameter
    - ns timing, dark < 30 kHz
    - ps timing, dark ~ 10 MHz