Position sensitive photon detectors using epitaxial InGaAs/InAlAs quantum- well

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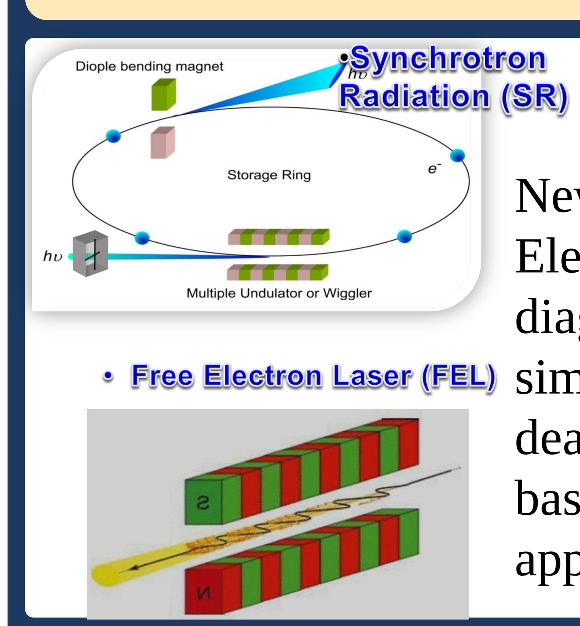
University of Surrey – 10th International Conference on Position Sensitive Detectors · iom Istituto Officina dei Materiali · Elettra Sincrotrone Trieste · Università degli Studi di Trieste – PHD school in Nanotechnology



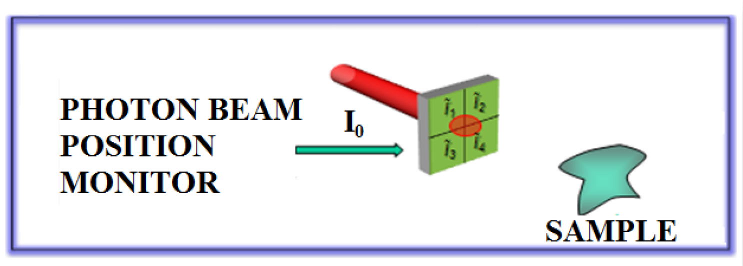
INTRODUCTION

New generation Synchrotron Radiation (SR) sources and Free Electron Lasers (FEL) require novel concepts of beam diagnostics to keep photon beams under surveillance, asking for simultaneous position and intensity monitoring [1]. This work deals with investigation of novel position-sensitive devices based on InGaAs/InAlAs Quantum Well (QW) for several applications of either synchrotron or conventional light sources.

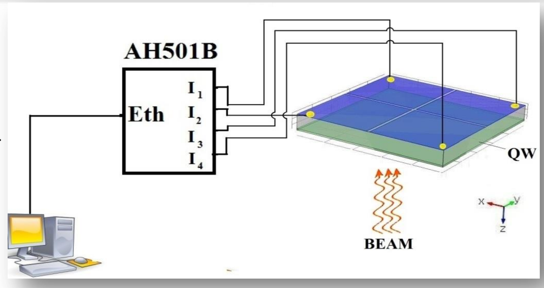
STATE OF THE ART

Due to their direct, low-energy band gap and their high electron mobility, InGaAs/InAlAs quantum-well (QW) devices operated at room temperature (RT) may be used as fast detectors for photons ranging from visible light to hard X-rays. Epitaxially grown devices are more homogenous, reproducible and need lower bias with respect to other solid state position sensitive detectors [2]. Photo-generated currents obtained from each electrode allow both the position and the intensity of the impinging beam to be monitored.

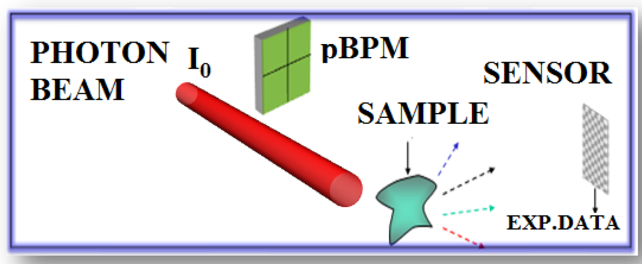
Working principle of solid state position estimation detector



MEASURE THE CURRENTS



ESTIMATE POSITION OF A BEAM



PERFORM MEASUREMENTS ON A SAMPLE

InGaAs/InAlAs QUANTUM WELL DETECTORS

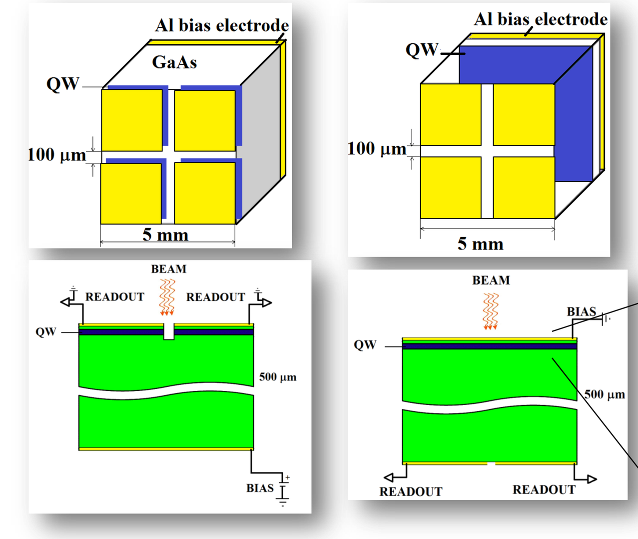


Fig 1. Schematic view of the fabricated devices

	Device #1	Device #2
Quantum-well segmentation	Yes	no
Clearance	100 µm	100 µm
Read out electrodes (segmented)	50nm Al on QW side	20/60/130 nm Ni/Ge/Au on back side
Single electrode as surface biasing	400nm Al on back side	400nm Al on QW side

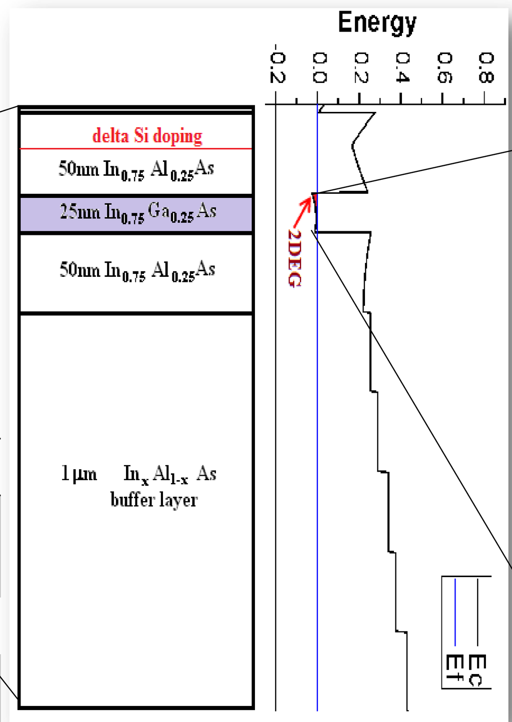
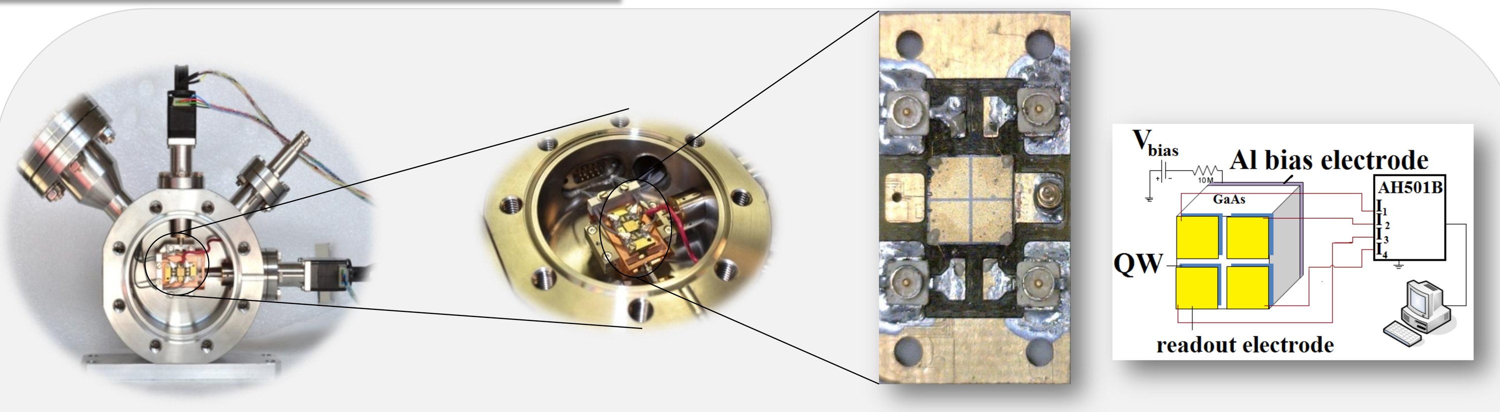


Fig.2. Layout of the sample structure with band structure

- 25-nm-thick QW, Si-δ-doped [2]
- **2D Electron Gas (2DEG)** inside QW with

Carrier density
$n = 7.7\times10^{11}$ cm^{-2}
Carrier mobility
$\mu = 1.1\times10^{4}$ cm^{2} V^{-1} s^{-1} at room temperature



- Photo-generated carriers can be collected at the readout electrodes by biasing form either the QW side or the back side of the devices during beam exposure.
- Individual currents obtained from each electrode allow to monitor both the position and the intensity of the impinging beam for photon energies ranging from visible to hard X-ray [3].

RESULTS

Fastness of the device

Device#1 was tested with a 400-nm, 100-fs table-top laser. The device responded with 100-ps rise-times to such ultra-fast laser pulses (Fig.3).

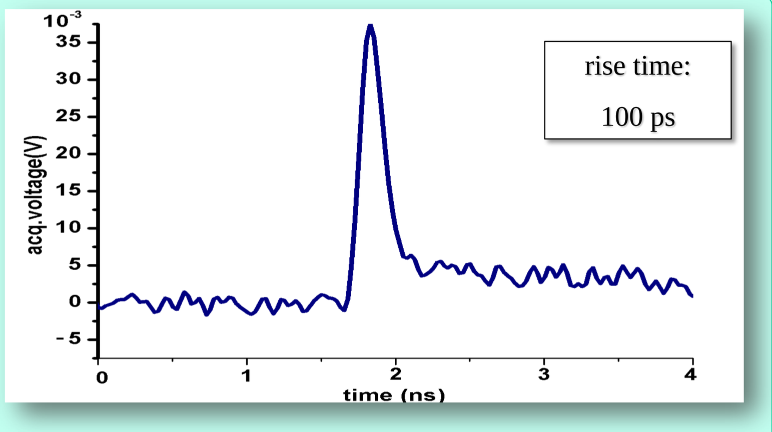
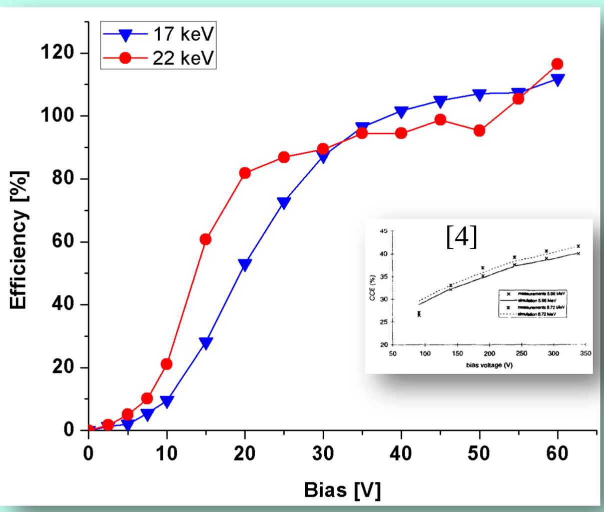


Fig 3. Sub-ns response to near UV laser pulses

Photo-generated charge collection efficiency



The results obtained with X-ray SR at 17 keV and 22 keV show how these devices exhibit high charge collection efficiencies, which can be imputed to the charge-multiplication effect of the 2DEG inside the QW (Fig.4).

Fig 4. Photo-generated charge collection efficiency of QW samples compared with bulk GaAs solid detectors [4]

Position estimation of Synchrotron light

Device #2 was tested by SR in the range of energies from 2 keV to 10 keV, in order to estimate the position of the beam with different spot sizes of 70 µm and 500 µm.

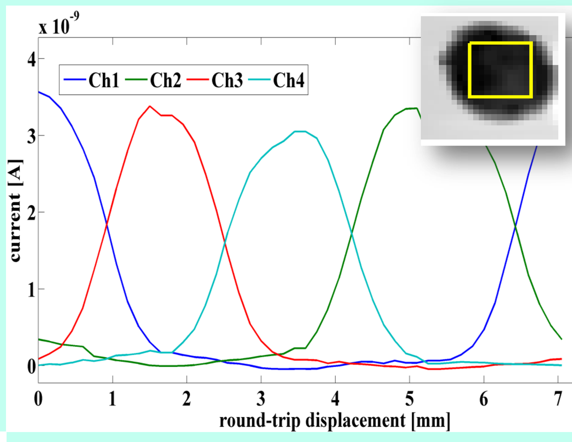


Fig.5.Current trends along a yellow-square-shaped path around the surface of the QW device at 2 keV.

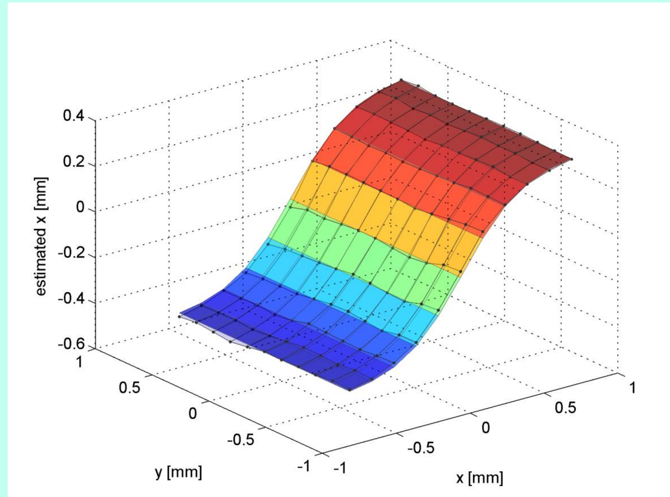


Fig.6. Horizontal-position estimation in terms of real beam position. Data (marked by dots) are fitted with a sigmoidal function (at 10 keV)

The position of the beam was estimated with precisions of ~10 µm with 500-µm spot (Fig.6) and ~0.8 µm with 70-µm spot (Fig7).

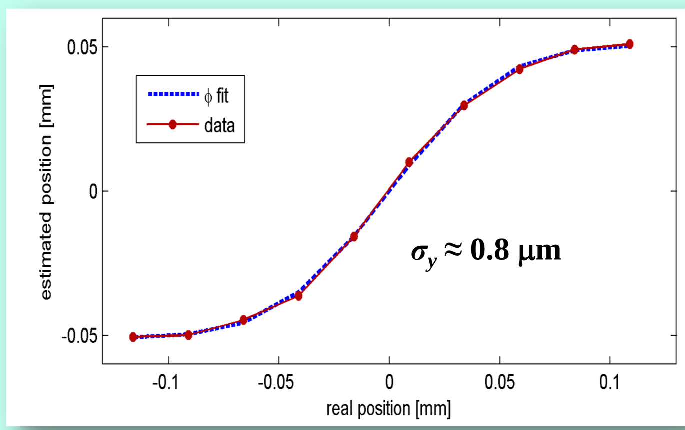


Fig.7. Vertical-position estimation (at 7 keV)

Conclusions and Significance

InGaAs/InAlAs quantum-well devices were tested with Synchrotron Radiation (SR) and 400-nm laser light. Those devices responded with 100-ps rise-times to such ultra-fast laser pulses and showed enhanced collection efficiency for photo-generated charges. In SR measurement, we have estimated the beam position with spatial precision ~0.8µm with pink needle beam (size-70µm).

References:

1. A. Galimberti et al., *Nucl. Instrum. Meth.* **A 477**, 317-322 (2002).
2. F. Capotondi et al., *Thin Solid Films* **484**, 400-407 (2005).
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