“OPTICAL DIAGNOSTICS”

A new EUREKA Project E!4473

(2008.07 – 2011.06)

Partners:

1. Vilnius University (Lithuania)
2. SME EKSPLA UAB (Lithuania)
3. AIXTRON Company, Germany

Coordinator: prof. habil. dr. K. Jarašiūnas
Institute of Mat. Sci. and Applied Research, VU

FULL TITLE:

Novel optical measurement technologies and devices for diagnostics of advanced semiconductors

A PRINCIPAL GOAL:

Implement **novel** measurement technologies and **tools** for characterization of advanced semiconductor materials and for ***ex-situ*** **evaluation of their fabrication technologies**

Approach: Production and exploitation of new scientific knowledge.
Such an approach is essential to tackle the "European paradox“.
The European paradox is that there is a strong science base but weak innovation performance (exploitation).

Question: Do we need novel techniques?

YES !

Knowledge of carrier dynamics is the key issue in most technologically important materials. Therefore techniques able to provide important ***electronic*** parameters, which reflect a material quality and may predict its operation as a device, are on demand.

Solution: characterize the fast electronic properties of a semiconductor by optical means

The standard techniques- *electrical*, *linear optical* spectroscopy and *photoliuminescence* are not well suited for monitoring fast processes: they need contacts, *are time-integrated, or has no radiative PL signal !*

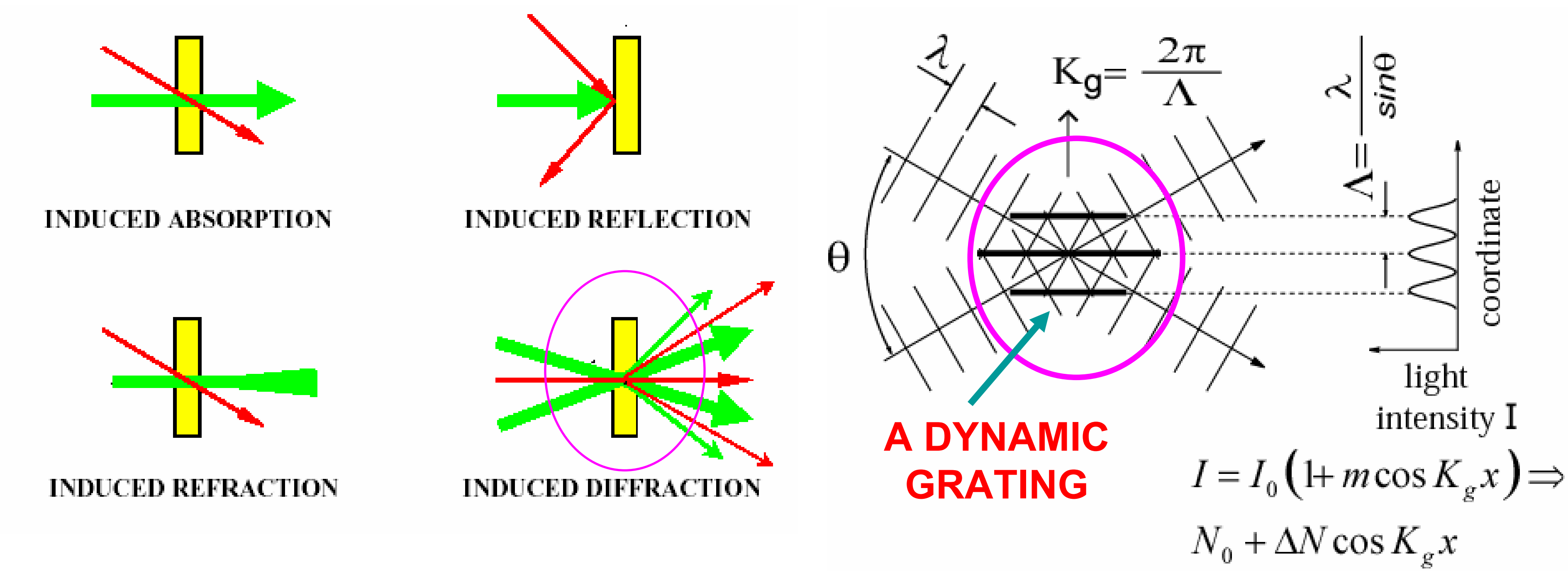
A problem: HOW to implement a potential of Time-Resolved techniques?

Answer: By using laser-assisted "pump-probe" *techniques,* which are based on a light-induced modulation of electronic and optical properties, and subsequent monitoring of relaxation processes by optical means.

This approach will bridge the **photoelectric properties and optical nonlinearities of a semiconductor**

A technique *of dynamic holography* has the highest metrological potential. To apply it, one must know how to write a dynamic hologram, how to read it, and how to extract information about a material properties

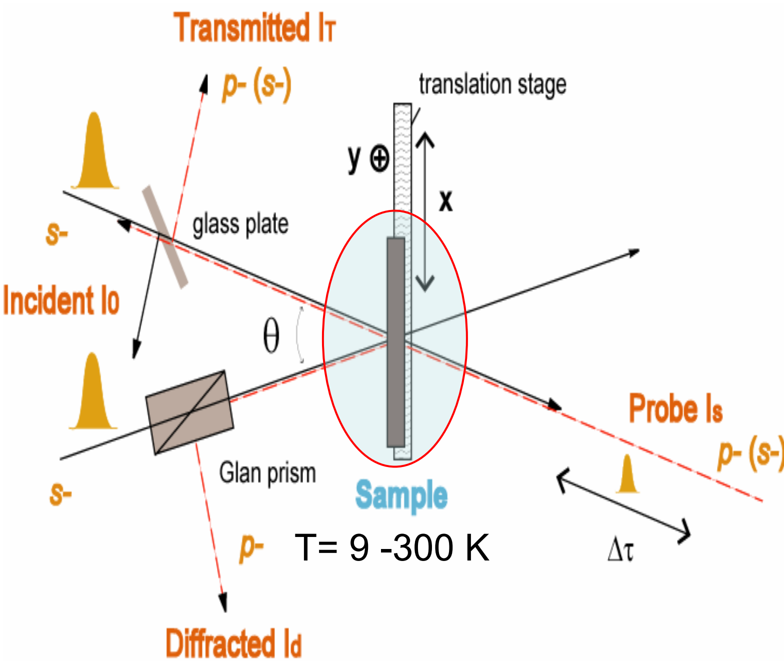
“Excite-probe” configurations for nonlinear optical experiments



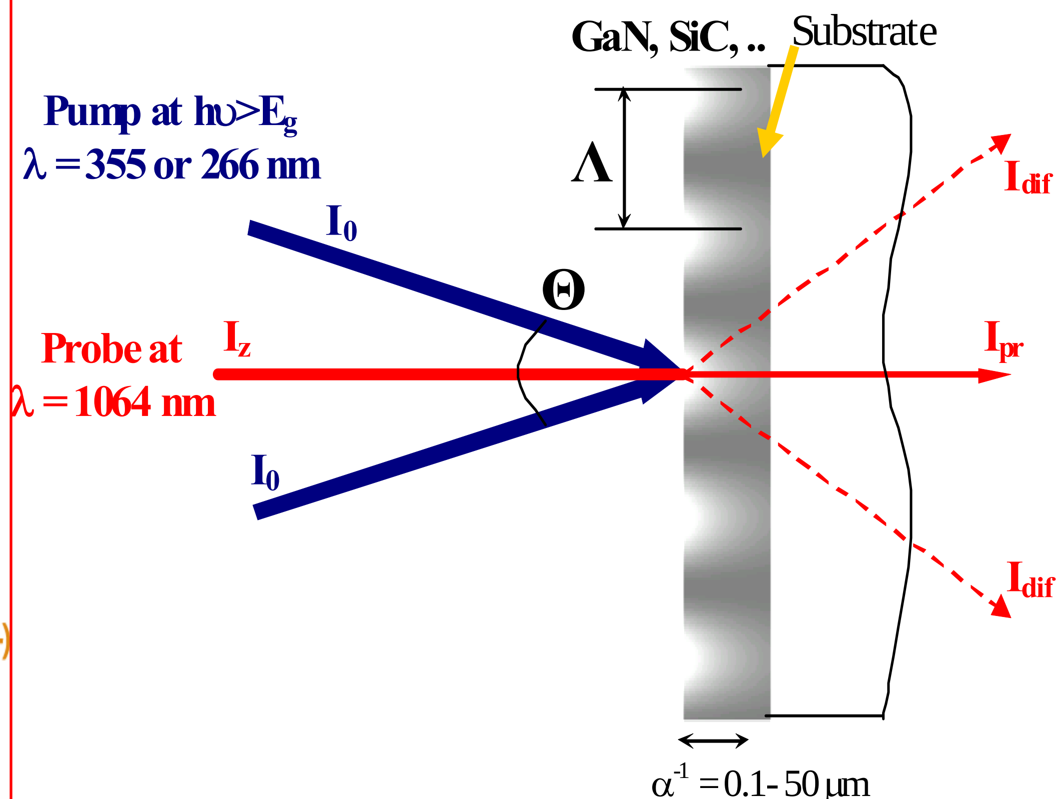
Information about refractive index spatial and temporal modulation *Δn* (x,t) ∝ *ΔN (x,t)* is read by light diffraction light and will provide electronic parameters τ and D

Transient gratings: a “bulk“ and “surface” cases

Experiments at excitation
below Eg, $\alpha d < 1$
e.g. GaAs, CdTe, Si (at 1064 nm)
or GaN, SiC at 2.34 eV



pump at $\alpha d >> 1$



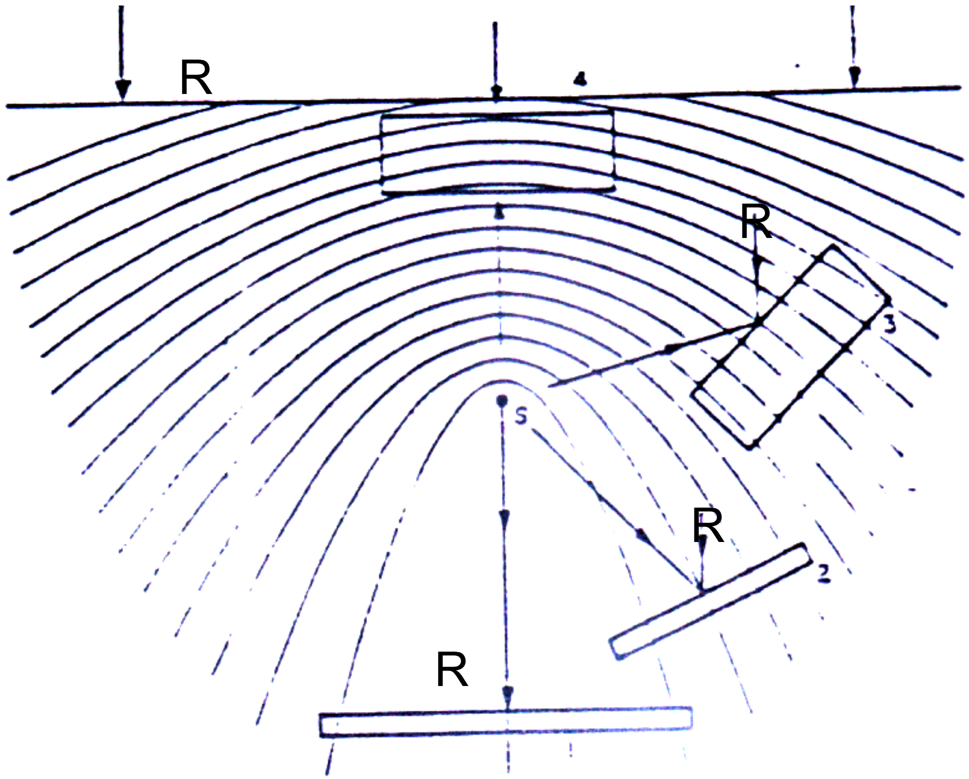
$$\tau_e = f\left(\Lambda^{-2}\right): \quad \frac{1}{\tau_e} = \frac{1}{\tau_R} + \frac{1}{\tau_D} \Rightarrow \tau_R, \mathrm{D};$$

$$\eta = f\left(I_0\right): \quad \eta \sim (\Delta N)^2 \sim I_0^{\gamma}$$

$$\Lambda \approx \lambda / \sin \Theta$$

$$\Theta\ [2 \ldots 7\ ^{o}] \Rightarrow \Lambda\ [20 \ldots 3\ \mu\mathrm{m}]$$

Optical geometries for hologram recording

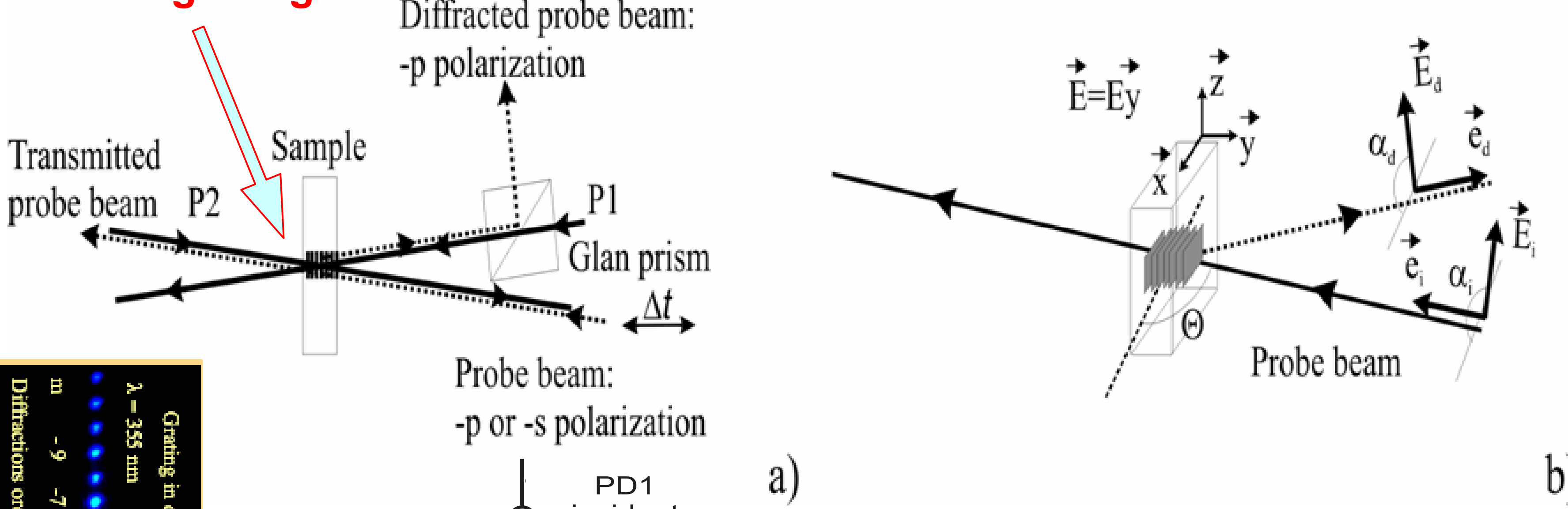


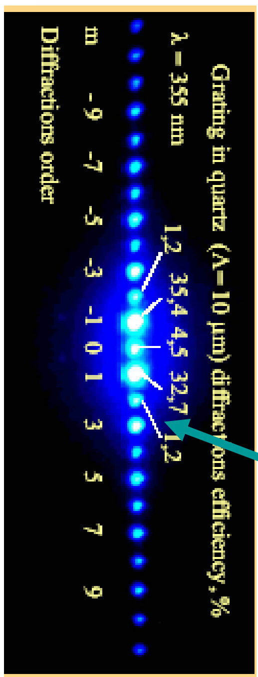
Plane reference wave R interacts with the sactterd by object wave S:

1 – axial geometry (D. Gabor/1951); **2 - Leith - Upatnieks** (1962), d<Λ, thin grating ; **3 – thick grating**, d>Λ, Bragg difrakction; **4 – reflection grating** (d>>Λ= λ/2); here d is the thickness of a recording material

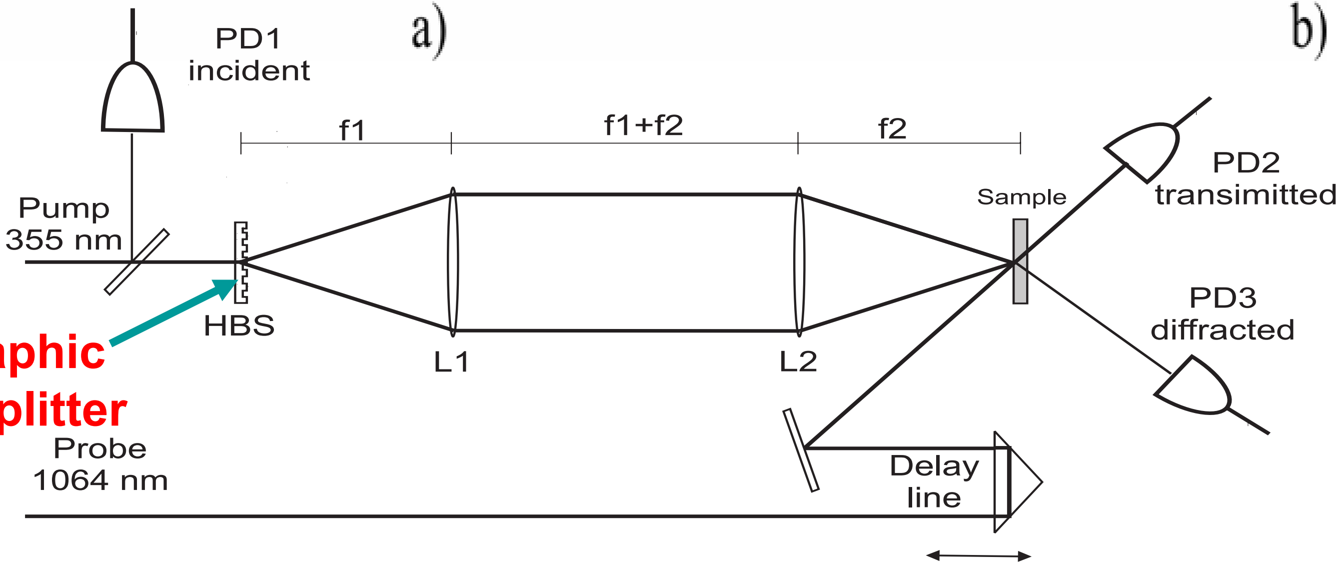
New optical schemes under development

Reflection grating



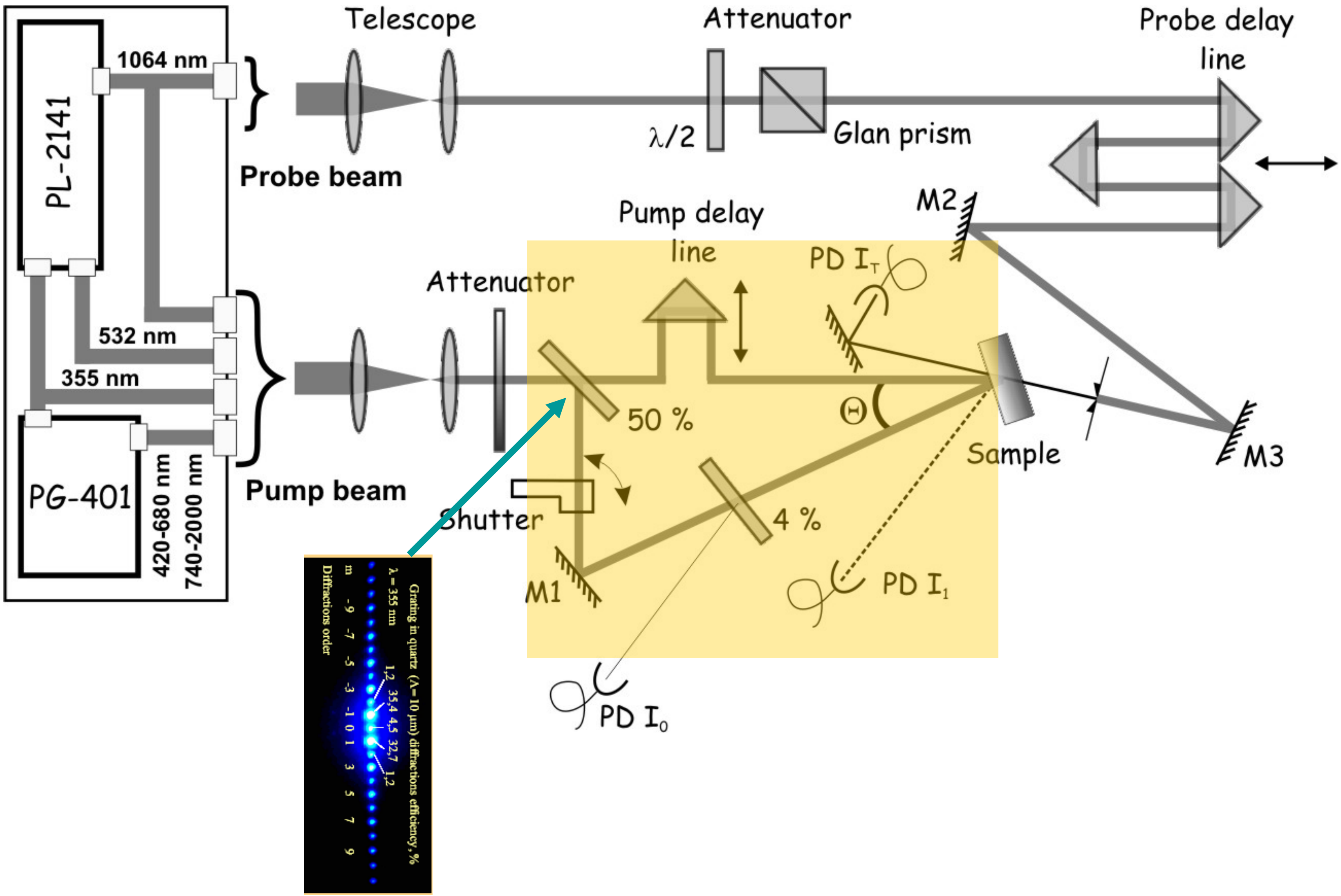


Holographic beam-splitter

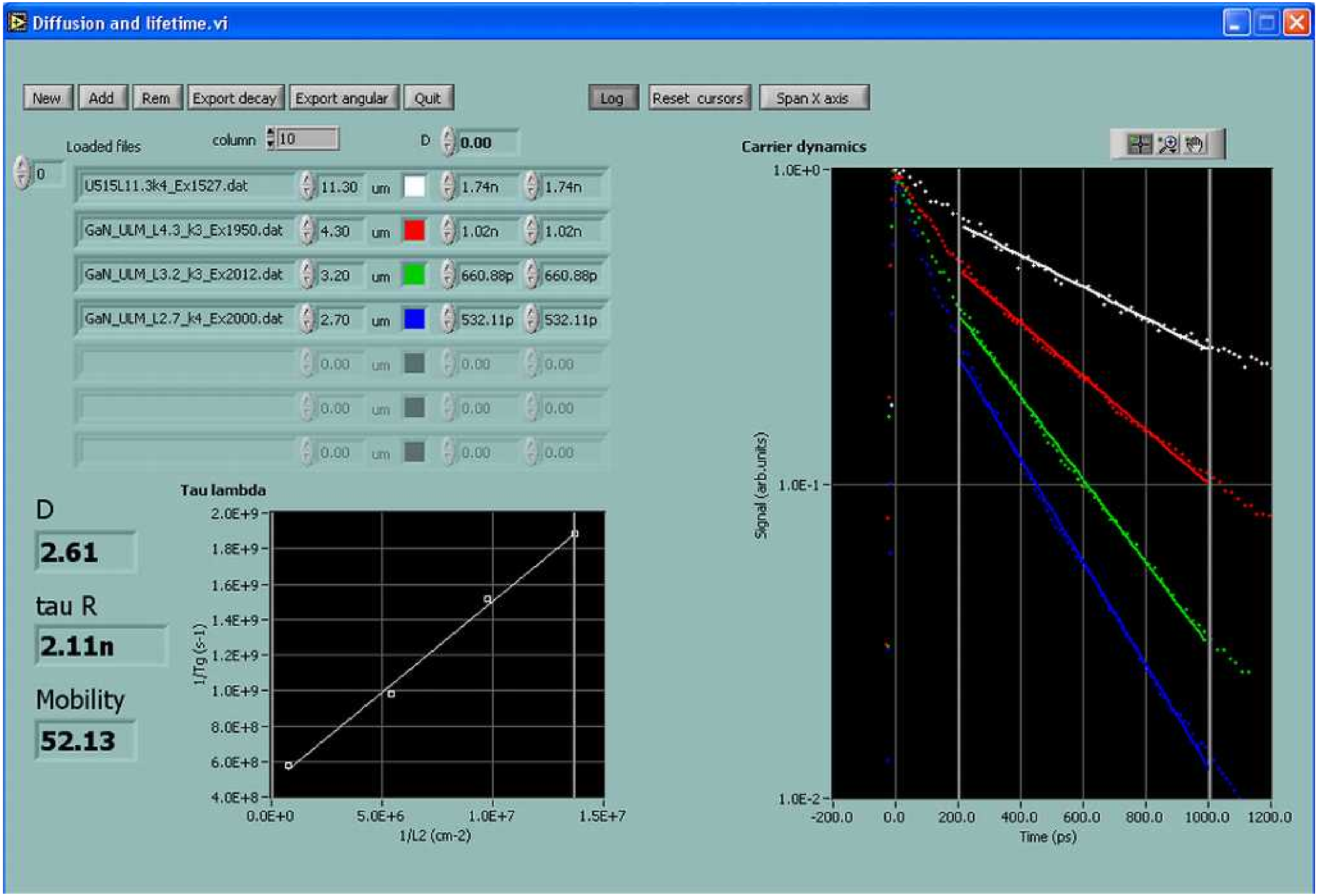


REVIEW OF SCIENTIFIC INSTRUMENTS **78**, 033901 2007

TASK: Modify a setup of picosecond transient gratings

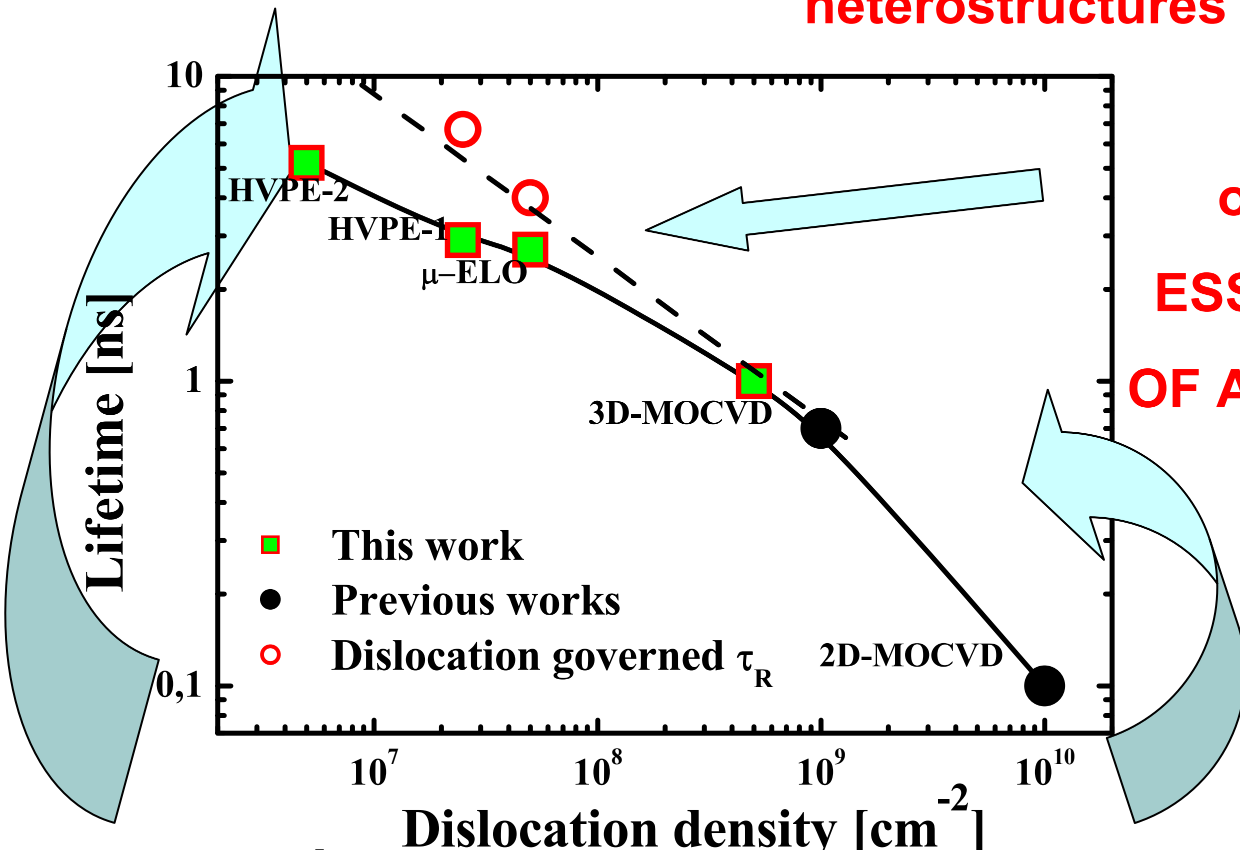


Data analysis by Labview



EXAMPLE: Competition of nonradiative and radiative recombination in LED materials

$$1/\tau_R = 1/\tau_{nonRad} + 1/\tau_{Rad}$$



Different growth-technologies of GaN heterostructures and substrates

on sapphire,

on Si, on SiC

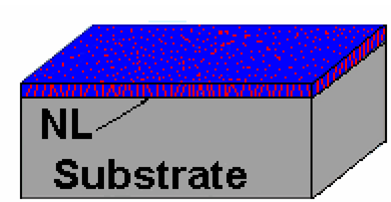
ESSENATIAL ROLE

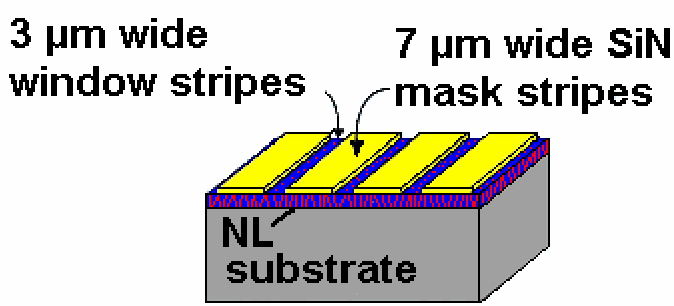
OF A BUFFER LAYER

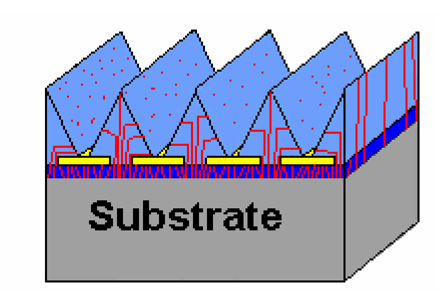
- **Low dislocation** density - radiative recombination is the contributing recombination channel

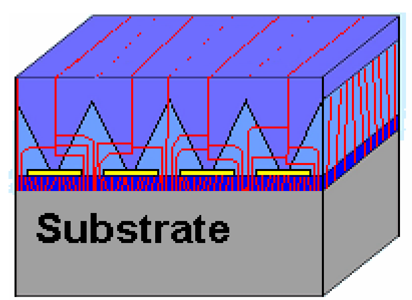
- **High dislocation** density case - lifetime is governed only by the nonradiative recombination

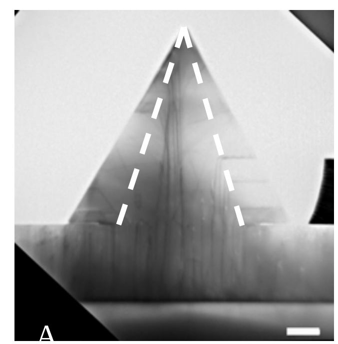
ELO growth: using a mask and advanced 3D-growth without a mask (growth in AIXTRON MOCVD reactor)

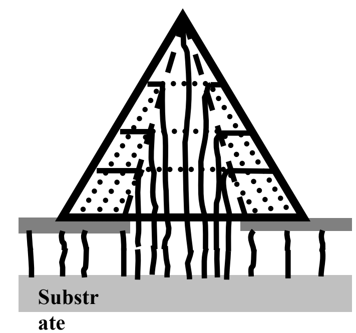




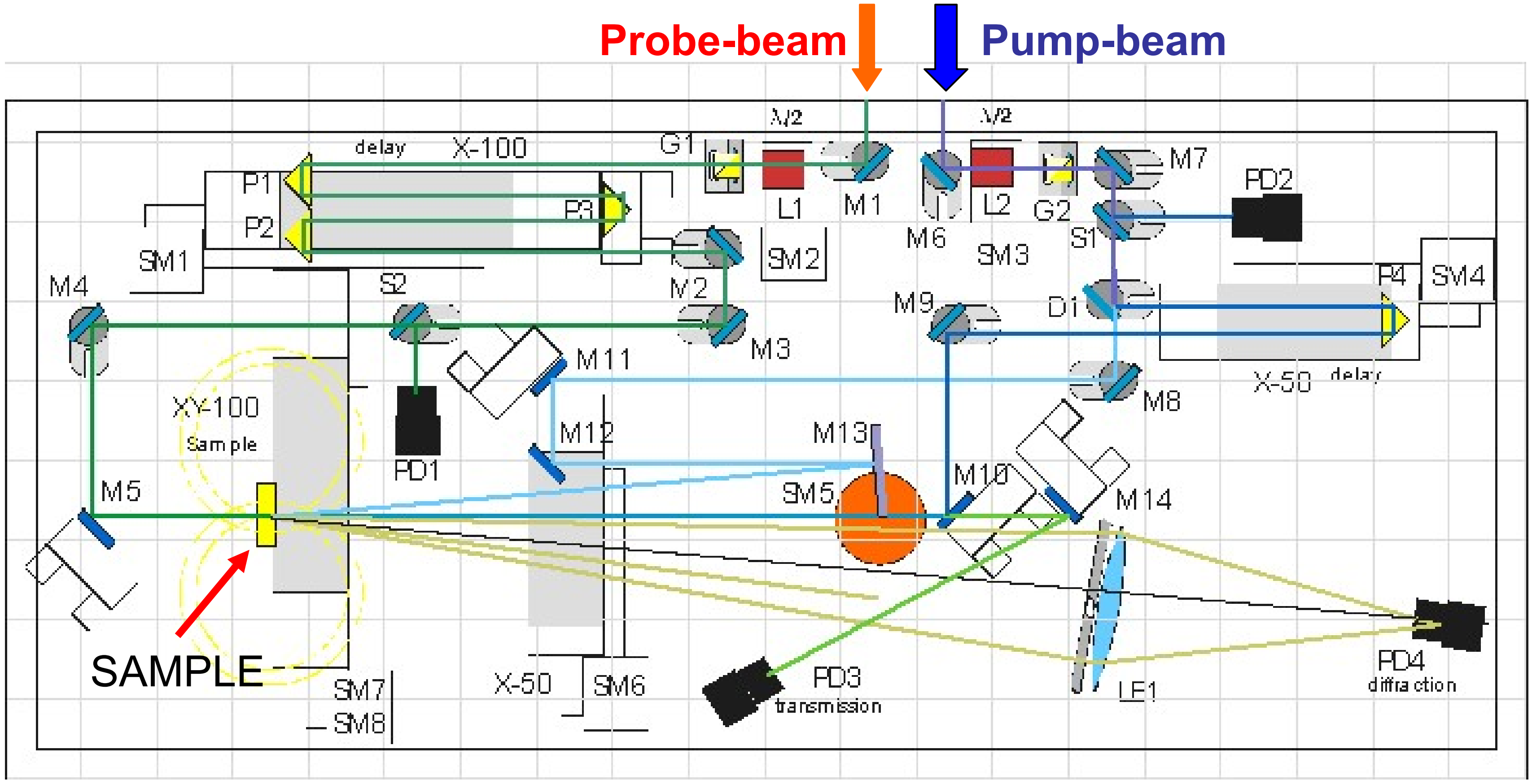








A pilot device: HOLO-module



Module HOLO-2 (Ekspla Co.), as a part of a measurement system at RPI (USA)

Metrological potential of HOLO-2 was demonstrated by optimizing the growth of a buffer layer for UV LED structure

SET Co, USA became a worldwide leader in fabrication of deep UV LEDs

EUREKA Project WORKPLAN

1. **<u>Scientific tasks:</u> Advanced all-optical characterization, modeling, and development of algorithms for materials characterization (GaN, InGaN, InN, AlGaN, SiC, ZnO, diamonds) ⇒ a software for a novel diagnostic tool (We need partners who grow advanced materials for optoelectronics)**

2. **<u>Technological tasks</u>: testing and implementation of a holographic beam splitters (HBS) and their arrays, optimized for the specific wavelengths ⇒ a hardware for a novel diagnostic tool**

3. **<u>Engineering</u> tasks: Design and assembling of a pilot device**

Thank you for attention!