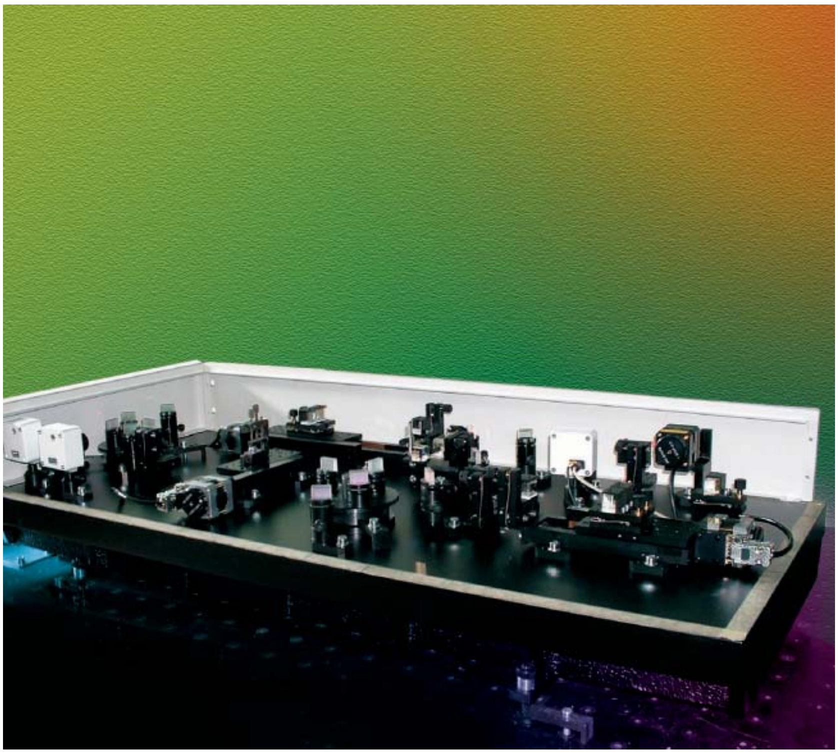


HOLO MODULE

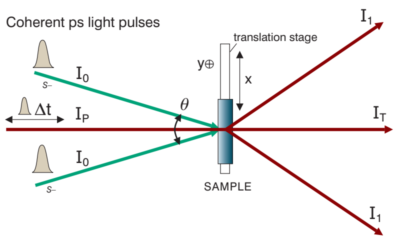
HOLO module

Holographic device for measurement of semiconductor photoelectric parameters

HOLO-module is a novel device for contactless investigation and optical diagnostics of carrier generation, transport and relaxation processes in bulk semiconductor crystals, epilayers, and heterostructures. It explores a **four-wave mixing configuration** of the well-known **"pump-probe" technique**. The operation is based on the recording of a refractive index spatial modulation by interference field of the two picosecond laser pulses and subsequent probing of the modulation decay by the delayed probe beam. **HOLO device** allows measurement of *carrier generation rate*, photoinduced *carrier concentration, bipolar diffusion coefficient, carrier recombination time* and *surface recombination rate*. The device also allows planar monitoring (mapping) of diffraction efficiency and extracting the homogeneity of defect distribution in a wafer.

BASICS OF OPERATION

Two coherent laser pulses overlap in the sample at angle 2Θ and create an interference pattern with period $\Lambda = \lambda/2\sin(\Theta/2)$. The interband transitions or impurity-assited carrier generation creates a spatially modulated nonequilibrium carrier distribution $N = N_0(1+\cos 2\pi x/\Lambda)$, which, in turn, is followed by a periodic refractive index modulation $\Delta n(x,t) \sim \Delta N(x,t)$. In this way, a dynamic free carrier grating is recorded in a semiconductor. The grating is probed by a delayed third beam at the wavelength far from the bandgap, and thus is partially diffracted on the grating. The energy of the diffracted I_1 and transmitted I_T parts of the probe are recorded in the far field of diffraction, and the instantaneous diffraction efficiency of



the grating $\eta = I_1/I_T$ is calculated. The diffraction efficiency, being nonlinearly dependent on the modulated part of the refractive index, $\eta \sim n^2$, sensitively reflects the changes of ΔN, thus providing carrier relaxation kinetics. Therefore, the HOLO-module allows optical studies of the carrier transport and determination of number of photoelectrical parameters, important for evaluation of semiconductor technology.

FEATURES

- Grating recording wavelength 266, 355, 532 or 1064 nm
- Probe beam wavelength 532 or 1064 nm
- Excitation energy flux density 0.1–10 mJ/cm^2
- Probe beam delay range 1500 ps
- Laser pulse duration range 5–50 ps
- Dynamic grating period range 2–20 µm
- Minimal probe beam diameter 100 µm

RANGE OF MATERIAL PARAMETERS

- Diffusion coefficient ***D*** – 0.1–50 cm^2/s
- Carrier lifetime τ_R – 0.1–10 ns
- Surface recombination velocity ***S*** – 10^4–10^6 cm/s

EKSPLA

EXAMPLES OF PARAMETERS DETERMINATION

DETERMINATION OF DIFFUSION COEFFICIENT *D* AND CARRIER LIFETIME τ_R

Diffraction efficiency η as a function of probe delay time Δt is called the grating decay kinetics, $\eta(\Delta t)$. The kinetics is measured for a selected grating period Λ, and the grating decay time τ_G (the time interval in which the diffraction efficiency decreases by e^2 times) is determined. In this time interval, the carrier modulation decays by *e* times due to carrier recombination and diffusion according to relationship $1/\tau_G = 1/\tau_R + 4\pi^2 D/\Lambda^2$. Thus, measuring a set of diffraction efficiency kinetics at different periods Λ allows to plot a function $1/\tau_G = f(\Lambda^{-2})$ (so called an angular characteristic) and extract the *D* and τ_R values from a linear fit of the latter plot.

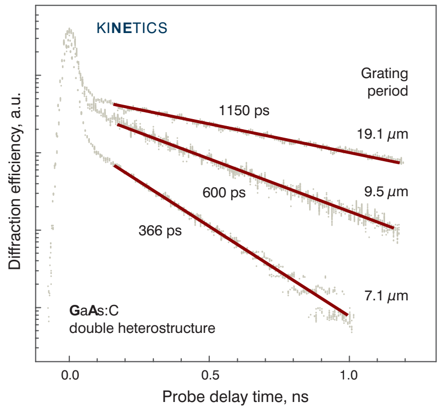


Figure a). *The grating decay kinetics at various grating periods, measured in heavily doped GaAs:C double heterostructures, manufactured for HBT.*

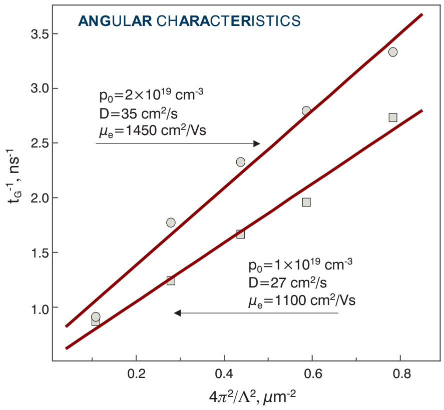


Figure b). *The angular characteristics for two differently doped GaAs:C double heterostructures. Linear fit of the latter characteristics provides the D and minority carrier mobility values in heavily doped GaAs:C layers.*

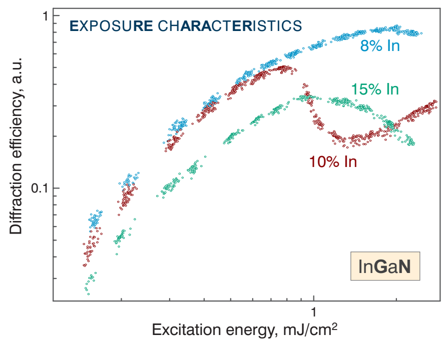
DETERMINATION OF SURFACE RECOMBINATION VELOCITY *S*

At band-gap excitation, the carriers are excited in a very thin surface layer (~ 0.1 – 0.2 µm), therefore surface recombination may take place until carrier diffuse away from the sample surface. The decay kinetics of a surface grating allows determination of a surface recombination velocity by numerical fitting of the non-exponential grating decay with a solution of two-dimensional contuinity equation.

DETERMINATION OF CARRIER GENERATION RATE

Measurement of diffraction efficiency vs. excitation density (so called exposure characteristic) provides an important information about carrier generation and recombination. A power law dependence of diffraction efficiency vs. excitation is characterized by its slope $\gamma = \Delta log(\eta) / \Delta log(I_0)$. γ value may vary from γ = 2 for linear interband carrier generation to γ = 4 for two-phonon carrier generation. The nonlinear recombination may diminish γ value causing a saturation of the exposure characteristic.

Figure c). *Exposure characteristics in 50 nm thick InGaN layers with different In content. The saturation of the characteristics at ~ 1mJ/cm² indicates the threshold of stimulated emission in InGaN layers.*



LASER LIGHT SOURCE

Ekspla **PL2140 series** picosecond lasers are highly recommended.

- High pulse energy at 266, 355, 532, 1064 nm
- Excellent pulse energy (<1,5 %) and duration (<1,0 %) stability
- All solid-state mode-locking

Requests for custom made products are welcome.

Contact person for more detail information:
Kęstutis Jarašiūnas,
e-mail: kestutis.jarasiunas@ff.vu.lt

EKSPLA

E K S P L A Ltd.
Lasers and Laser Systems Div.
Savanoriu av. 231
02300 Vilnius – 53
L I T H U A N I A

Ph.: +370 5 2649629
Fax: +370 5 2641809
sales@ekspla.com
www.ekspla.com