the pump beams), grating modulation depth (by changing the ratio of intensities of the beams) and probe beam (by operating in a suitable spectral region) mean that a wide range of parameters can be measured that are difficult to investigate using other methods.

Layered systems and superlattices are of particular interest. By generating a free-carrier grating and probing it in the spectral region lying outside the resonant interaction one can investigate free-carrier diffusion, recombination and redistribution within layers hidden beneath a transparent layer [5]. The high sensitivity is demonstrated by the fact that the influence of doped monolayers on neighbouring layers can be studied.

Moreover, the possibility to tune the excitation and probe beams over wide wavelength ranges allows one to determine the spectral properties of a bulk material or a structure. Defects in superlattices and their distribution have been analyzed by measuring recombination parameters [10], and details about defects, such as changes of the local field symmetry due to lattice deformation, can be probed with high sensitivity [11].

The analysis of effects related to free and localised carriers shows that diverse applications of the transient-grating technique are possible, in both fundamental research and applied fields. The most immediate application perhaps involves non-destructive techniques to investigate transport processes in semiconducting crystals and two-dimensional layered structures – a technique that may be suitable for the *in situ* control of production processes used in the electronics industry. Transient gratings excited by picosecond and nanosecond laser pulses have also been used to monitor the quality of crystals and layers as well as the annealing of defects introduced by thermal effects and by irradiation.

For instance, Vilnius University's Laboratory for Optical Diagnostics of Semiconductors has developed the D-SCAN instrument to monitor the homogeneity of GaAs wafers by mapping the distribution of dislocations and trapping centres. The laboratory has also developed the IMPLANT instrument to control very low doses of implanted ions (down to concentrations of 10^{12} atoms/cm^3 of B^+, P^+ or Ar^+) in Si wafers.

Finally, photorefractive gratings have potential applications in optoelectronics, high-speed information processing, phase-conjugated devices, real-time optical sensors, *etc.*

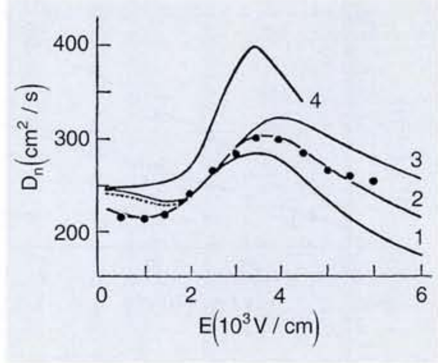

Fig. 4. The electric-field dependence of the diffusion coefficient of electrons in GaAs [8]. The solid curves correspond to Monte Carlo simulations for increasingly larger values of the coupling constant (1: 0.18 GeV/cm; 2: 0.3 GeV/cm; 3: 0.5 GeV/cm; 4: 1.0 GeV/cm). The points correspond to optical measurements made using transient gratings. They indicate that the diffusion coefficient is smaller than the predicted value at fields below about 2×10^3 V/cm owing to scattering on ionized impurities.

Future Developments

Non-linear optical polarizability becomes important at high laser intensities. Since this effect changes the refractive index of a crystal it may be possible to create a transient grating using a purely optical effect. Gratings of this type could be used to investigate the non-linear optical properties of semiconductors [12, 13].

Secondary effects related to energy transfer from the excited state to a lattice can arise in addition to free-carrier and non-linear optical effects. For instance, local heating induced in a crystal by light absorption and free-carrier recombination may lead to changes of the refractive index and the formation of a thermal grating, thus allowing the thermal conductivity to be measured using the decay of the grating [14]. Moreover, thermal expansion of the lattice can lead modulation of surface relief, with diffraction of the light reflected by the surface structure [15]. By examining time constants as well as the change in the sign of the refractive index it should be possible to separate out the various phenomena that lead to transient gratings.

Improved experimental techniques offer many opportunities. For instance, an increased sensitivity to free and bound carriers and to excitons would permit electronic properties to be probed deep within crystals and layered structures. The development of waveguide geometries other than thin-layer structures would allow excitation laser beams of reduced intensity to be used for samples that are sensitive to high-power laser light. Other geometries may not only decrease the laser intensity threshold at which the very interesting non-linear optical effect is observed but also open up other wavelength ranges. So techniques based on transient gratings clearly have a great potential for further development and application.

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Linac-Driven FEL Approved

Linac-driven free-electron lasers (FEL) providing short-wavelength (1-10 Å) coherent radiation with eight orders of magnitude larger peak brilliance compared to state-of-the-art synchrotron radiation sources seem to be feasible. They use self-amplified spontaneous emission whereby an electron beam of sufficient quality passing a long undulator magnet exponentially amplifies an initially existing radiation field.

DESY Hamburg's HASYLAB has been given the go-ahead to integrate a FEL in the TESLA test bed facility that is under construction [see *EN* **25** (1996) 104]. A international collaboration plans is to demonstrate proof-of-principle of a 200 eV/60 Å VUV FEL by the year 2000. Several beams could be then extracted from the linac and piped to a synchrotron users laboratory where they would be switched between several undulators.

Linac-driven x-ray FELs are being considered in the context of a future 500 GeV, 30 km long high-energy linac for particle physics (the linac's first section would provide 1 Å radiation). A final draft of a US design is expected shortly and a Japanese design report is due next year. Meanwhile physicists are studying opportunities offered by linac-driven FELs' exceptionally bunch brilliance.