ing in the surface-plasmon dispersion curve observed by Arakawa *et al.* is obtained from Fresnel's equations. Furthermore, this result is *not* inconsistent with the asymptotic behavior previously observed. A correct interpretation of the ATR reflectivity minima in terms of dispersion curves requires a plot of reflectance versus both incident photon energy and incident angle and a consideration of the experimental method. Backbending will occur when the energy is fixed and the incident angle varied. Asymptotic behavior will occur when the incident angle is fixed and the energy varied. Finally, the minima observed for photon energies above the surface-plasmon frequency (i.e., for photon energies where $\epsilon_1 > -1$) are consistent with Fresnel's equations, and are due to ϵ_1 going through zero at the bulk-plasmon frequency.

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Dislocations as a Model for One-Dimensional Systems: Magnetoabsorption in Strained Te

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Tellurium crystallizes in parallel-packed helixlike chains of covalent-bound atoms. The bonds between the chains are much weaker than the ones within the chains; thus the dislocations in Te arrange themselves parallel to the crystallographic c axis to avoid cutting covalent bonds. Electrons bound to the dislocation lines therefore form quasi-one-dimensional states. We used magneto-optical absorption to study the nature of these bound states. They split up into highly anisotropic sub-bands, depending on strength and orientation of the magnetic field.

The absorption spectra at the band edge of Te show a pronounced anisotropy[1] originated by the allowed and forbidden direct transitions for the two polarization directions.[2] A sharp absorption line in the spectra for $\vec{E} \parallel \vec{c}$ was previously interpreted as an exciton.[3-5] By using highly polarized light it can, however, be shown that the shape of the line discussed there results from an

experimental artifact.[6]

In this paper we show that the optical properties of Te at the band edge are dominated by the defect structure, which is quite contrary to other solids. In particular, we show that the effects seen are intrinsically connected to the fact that the dislocations form a quasi-one-dimensional system of bound electron states.

Te is plastic down to temperatures of liquid nitrogen.[7] Therefore it is possible to create a high density of homogeneously distributed, defined dislocations in a controlled manner. The Te lattice has strong covalent bonds between the atoms along chains and favors dislocations which do not crack these bonds. Therefore the dislocations arrange themselves predominantly parallel to the crystallographic c axis.[6,8] The influence of crystal deformation on the optical properties of Te crystals at the energy gap was systematically investigated.[6,9,10]

The highly pure Te crystals ($p = 5\times 10^{14}$ cm^{-3}) were deformed in the prismatic a-glide system[6] which has the lowest elastic limit in Te.[11] Most of the dislocations introduced by plastic deformation are of the a-edge type, i.e., their dislocation line is parallel to the c axis. Optical absorption in the near-infrared region shows that strained samples have additional levels in the gap[6] (see Fig. 1, dashed curves). These lines are not due to point defects (e.g., jogs) which we can clearly show by annealing experiments.[10] The piezoelectric effect should also be inactive since the dislocations are of the edge type without line charge.[12]

On the basis of these experiments a dislocation-induced electronic sub-band in the gap of Te was proposed.[6] This band seems to be caused by bound-electron states in the dislocation core which form a band as a result of the conservation of the translational symmetry along the dislocation line. This subject was theoretically studied by Brown.[13]

The parallel orientation of the dislocation lines in Te makes this system particularly suited for examining the influence of the magnetic field orientation on the electron density of states in a linear perturbation potential. In our experiments we compared the same strained and undeformed samples whose absorption spectra in zero magnetic field were reported elsewhere.[6]

The magnetoabsorption spectra of deformed and undeformed Te differ strongly.[9] Measurements of the forbidden transition ($\vec{E}\parallel\vec{c}$) in magnetic fields up to 6 T were made for both Faraday and Voigt configurations. Figure 1 shows the additional lines appearing in the spectra of strained samples. In this case the direction of the magnetic field is parallel to the dislocation lines ($\vec{B}\parallel\vec{c}$). Comparison of the spectra of strained samples for zero and nonzero magnetic field shows that the magnetic field causes splitting of the dislocation-induced line structure. Furthermore, satellite levels appear near the lines, which may be interpreted as Landau transitions because they also appear in the undeformed samples.

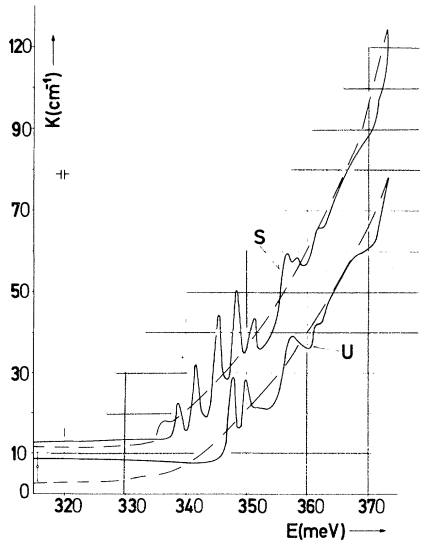

FIG. 1. Interband magnetoabsorption spectra of the forbidden transition, $\vec{E}\parallel\vec{c}$. Magnetic field orientation parallel to the dislocation line, $\vec{B}\parallel\vec{c}$; $B = 6$ T; $T = 10$ K. U, for the undeformed sample. S, for the sample strained in a prismatic a-glide system. (Dislocation density $\rho_D = 10^8$ cm^{-2}.) Dashed lines, absorption spectra without magnetic field, following Ref. 6.

The magnitude of the additional absorption in the magnetoabsorption spectra is a function of the dislocation density. Figure 2 shows this for the orientation $\vec{B}\perp\vec{c}$. In the undeformed material, $\rho_D = 10^4$ cm^{-2}, sharp lines are shown which can be interpreted as Landau transitions. This value $\rho_D = 10^{-4}$ cm^{-2} is representative for the best undeformed material in Czochralski-pulled[2] and carefully handled Te single crystals when measured by the etch-pit technique.[14] In Fig. 2 the magnetoabsorption spectra in the configuration $\vec{B}\perp\vec{c}$, as functions of the dislocation density, are shown. With augmentation of the dislocation concentration, the sharpness of the Landau transition peaks decreases while the dislocation-induced sub-band splits into several lines depending on the dislocation concentration. At concentrations greater

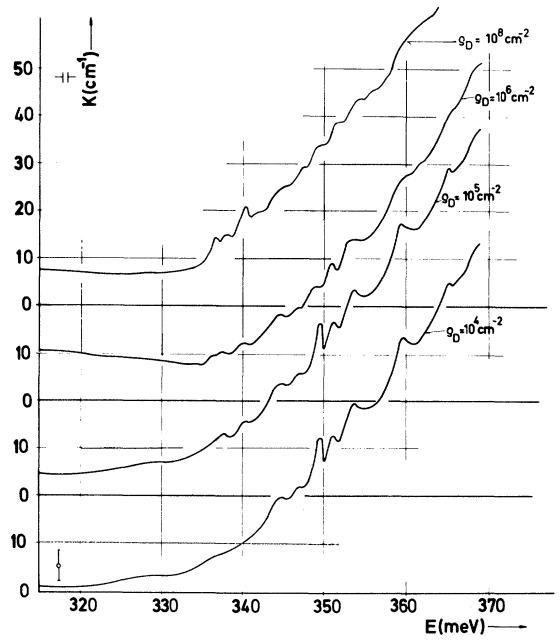

FIG. 2. Magnetoabsorption spectra of Te for samples with different dislocation densities. Forbidden transition, $\vec{E} \| \vec{c}$; magnetic field orientation perpendicular to the dislocation line, $\vec{B} \perp \vec{c}$; $B = 6$ T; $T = 10$ K.

than $\rho_D = 10^8$ cm^{-2} the dislocations are no longer homogeneously distributed. A polygonization of dislocations in crude walls takes place.[15] Therefore, measurements at higher dislocation densities have not been performed.

For the anisotropy with respect to the direction of the magnetic field we get the following result: In both cases, $\vec{B} \| \vec{c}$ and $\vec{B} \perp \vec{c}$, the dislocation-induced sub-band splits into different absorption lines. Only in the case of the magnetic field orientation parallel to the dislocation lines do additional levels appear for every Landau transition.

The problem of electrons bound to a line potential in an external magnetic field was treated theoretically by Brown,[13] Kosevich and Tanatarov,[16] and Kaner and Feldmann.[17] These authors in fact predict additional bands to appear below or above the Landau levels for attractive or repulsive potentials, respectively. A direct application of the theoretical results to our experiments would, however, require detailed knowledge of the electronic band structure and of the perturbing potential. An identification of absorption lines in such complex systems is always rather difficult as it involves a product of the densities of states of the valence and conduction bands, which are as yet insufficiently known for Te. The strong anisotropy of the gap and the presumably complicated dislocation potential introduce additional difficulties for quantitative analyses.

In spite of these difficulties we expect that deformed Te will prove an excellent example for studying one-dimensional systems, which have recently attracted great interest.[18]

At the same time, an important conclusion drawn from measurements is that any interpretation of optical spectra of Te has to include effects of the actual defect structure of the samples. Unless one has crystals with extremely low dislocation densities, it seems unreasonable to use the parameters of the undeformed material.[3-5,19] As we had crystals with an extremely low dislocation concentration, we were able for the first time to determine the magnetoabsorption spectra of nearly perfect Te samples. In particular, the dislocations give rise to an additional anisotropy which influences the galvanomagnetic as well as the magneto-optical effects.

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Critical Dynamics in $SrTiO_3$ from Paramagnetic Resonance

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Paramagnetic resonance line shapes and linewidths of the Fe^{3+}-V_0 center in $SrTiO_3$ above T_c permit the determination of an effective relaxation rate $\Delta\omega_l(T)$ for the local rotations of the oxygen octahedra by observation of the crossover from Lorentzian to Gaussian line shapes with different settings of the applied field. We find that $\Delta\omega_l$ decreases as $T \to T_c^+$, clearly indicating critical slowing down. In addition, the relaxation rate Γ_c for the R-point (order-parameter) collective mode is estimated from the linewidths in the region of Lorentzian shapes, indicating a "central peak" of width $\Gamma_c \approx 0.6 \times 10^8$ sec$^{-1} \approx 0.1\Delta\omega_l$ at $T = T_c + 2$ K.

The dynamic behavior near a structural phase transition is of considerable current interest.[1-3] In this Letter we investigate by EPR techniques the critical slowing down of rotational fluctuations of oxygen octahedra in $SrTiO_3$ above its antiferrodistortive phase transition. Our results provide quantitative information on how the *local* relaxation rate $\Delta\omega_l$ changes with temperature. Furthermore, we estimate the width of the "central peak" $\Gamma_c(T)$ dominating the *collective* scattering function $S(q, \omega)$ near T_c at the wave vector $q_R = \pi/a(\frac{1}{2}, \frac{1}{2}, \frac{1}{2})$ of the condensing soft mode. This has been observed with inelastic neutron scattering near antiferrodistortive phase transitions but its frequency width could not be resolved.[4-6] This observation has been the subject of numerous theoretical treatments[7,8] including a computer "experiment."[9]

In $SrTiO_3$ the EPR of the Fe^{3+}-V_0 center can be used as a sensitive probe to investigate the local rotation angles φ_l^{α} about a given axis $\alpha = \langle 001 \rangle$ when the applied field $\vec{H}$ and the center axis are in a (001) plane.[10] There the resonance magnetic field is given by $H_r = H_0 + A\varphi_l^{\alpha}$, where $H_0 = \hbar\omega/g_{\mathrm{eff}}\beta$. The dependence of g_{eff} and $A = \partial H_r/\partial\varphi_l^{\alpha}$ on angle θ between $\vec{H}$ and the center axis has been determined.[10]

As $T \to T_c$, the φ_l^{α} fluctuations result in a pronounced broadening of the linewidth ΔH.[11] This provides information on the local autocorrelation function $G^{\alpha\alpha}(t) = \langle \delta\varphi_l^{\alpha}(t)\, \delta\varphi_l^{\alpha}(0) \rangle$ or, equivalently, the local rotation spectral density

$$J_l(\omega) = (2\pi)^{-1} \int_{-\infty}^{+\infty} G^{\alpha\alpha}(t) e^{i\omega t}\, dt = N^{-1} \sum_q S(q, \omega). \quad (1)$$

Two limiting regimes of behavior are expected depending on whether the φ_l fluctuations are slow or fast in comparison with the magnetic relaxation $\Delta\omega$ they produce.[11,12] For very slow fluctuations the line shape is proportional to the probability $P(\varphi_l)$ to observe φ_l,[13] which may be a Gaussian distribution, giving a linewidth

$$\Delta H \simeq 2A\langle \delta\varphi_l^2 \rangle^{1/2} = 2A\left[\int_{-\infty}^{+\infty} J_l(\omega)\, d\omega\right]^{1/2}. \quad (2)$$

In this regime most of the area under $J_l(\omega)$ is concentrated at frequencies small compared with the resulting EPR linewidth $\Delta\omega = \Delta H g_{\mathrm{eff}}\beta/\hbar$. In the fast-motion limit, where $J_l(\omega)$ is spread out over a range wide compared to $\Delta\omega$, the observed lines should be Lorentzian in shape, and of width ΔH proportional to $J_l(0)$. More particularly, the angular frequency width between derivative extrema should then be

$$\Delta\omega = (2\pi/\sqrt{3}) B^2 J_l(0). \quad (3)$$

Here $B = g_{\mathrm{eff}}\beta A/\hbar$ is the parameter which measures the coupling of the instantaneous local EPR