Photocontrolled collective phenomena in TaS_3

S.V. Zaitsev-Zotov, V.E. Minakova

Institute of Radioengineering and Electronics of RAS
Moscow, Russia

ECRYS
August 2005

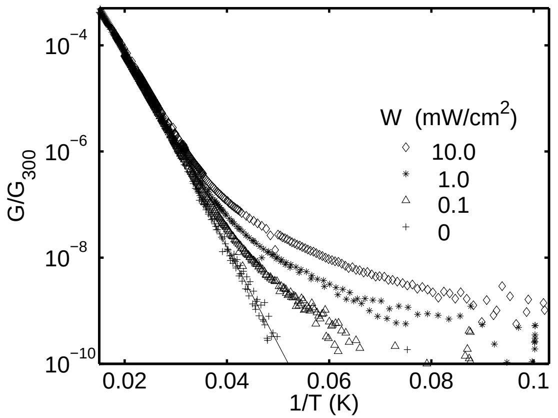
Outline

Is there photoconduction in q-1D condutors?

- Brazovskii, JETP (1980): lifetime of overgap excitations is small, $\sim 10^{-12}$ s (theory).
- Brill, Herr PRB (1983); Itkis, Nad', JETP Letters (1984): bolometric effect in TaS_3, no photoconduction.
- Gaál, Donovan, Sörlei, Mihály, PRL (1992): illumination results in nonlinear conduction growth in $K_{0.3}MoO_3$. No photoconduction.
- Demsar, Biljakovic, Mihailovic, PRL (1999): lifetime of nonequilibrium excitations in $K_{0.3}MoO_3$ is $\sim 5 \times 10^{-13}$ s.
- Ogawa, Shiraga, Kondo, Kagoshima, Miyano, PRL (2001). Illumination results in growth of E_T and CDW creep enhancement in $K_{0.3}MoO_3$. No photoconduction.

Outline

Appearance of photoconduction in TaS_3



TaS_3

$T_P = 220$ K

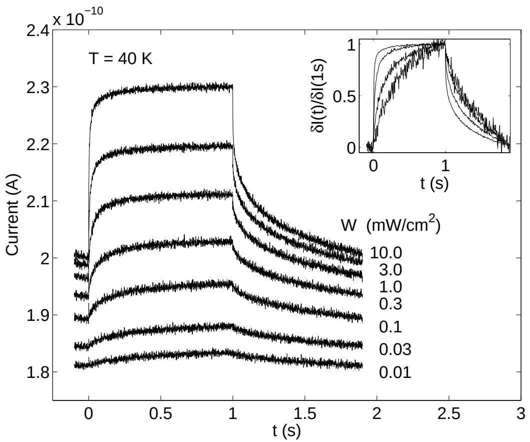
$\Delta = 850$ K

Estimates

$T = 100$ K

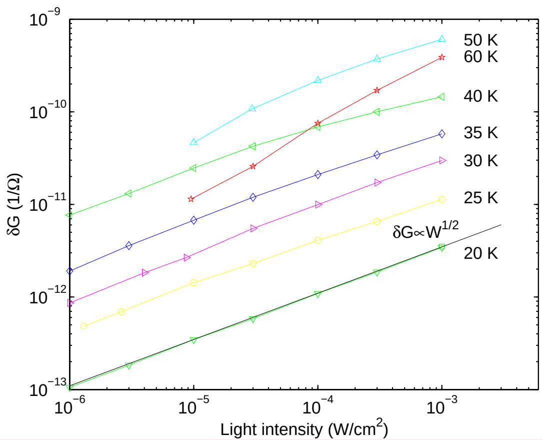
$\tau \sim 10^{-10}$ s

Photoconduction relaxation at $T \gtrsim 40$ K



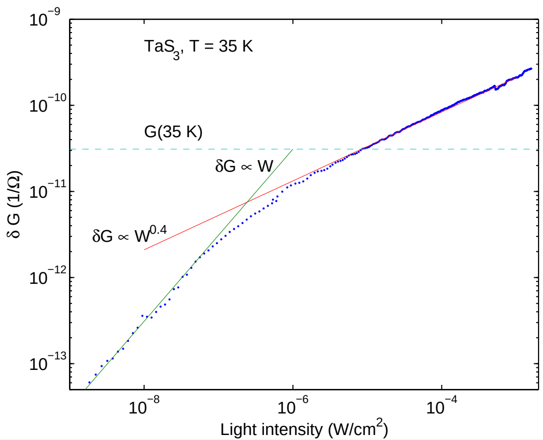
- Nonlinear response at $\delta G \ll G$
- Different time scales for onset and relaxation
- Intensity-dependent shape

Quadratic photoconduction relaxation



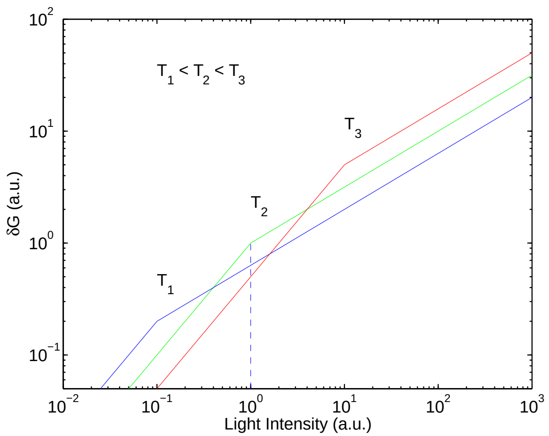
Quadratic relaxation
$\delta G \propto \sqrt{W}$

Linear-to-quadratic recombination crossover



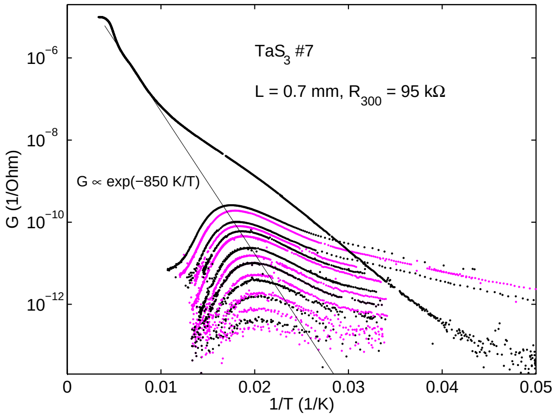
$\delta G_{crossover} \approx G_{ph}$
that means
$G_{tot} = G_{ph} + G$
where
$G_{ph} \ll G_{tot}$!!!

Linear-to-quadratic recombination crossover



For any ligh intensity $\max \delta G(W) = \delta G_{crossover}(W, T)$

Origin of photoconduction and low-temperature conduction



Origin of photoconduction and low-temperature conduction

In TaS_3 at $T < 100$ K photoconduction and conduction are provided by different physical mechanisms:

- Photoconduction is provided by electrons and holes optically excited over the Peierls gap
- Low-temperature conduction of TaS_3 is provided by collective excitations of the CDW (solitons) (see, *e. g.*, Takoshima *et al.*, *Solid State Comm.* (1980))

Outline

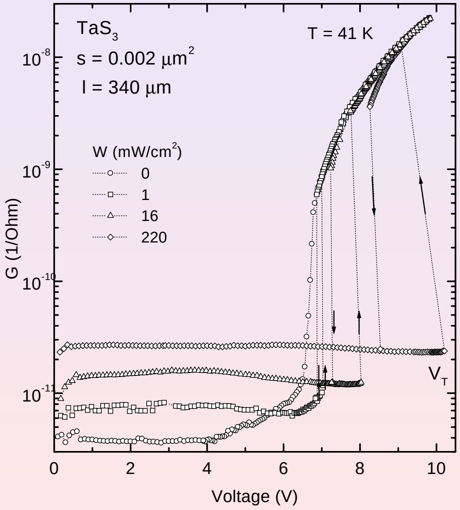
Illumination as a tool for collective phenomena study

Expectations

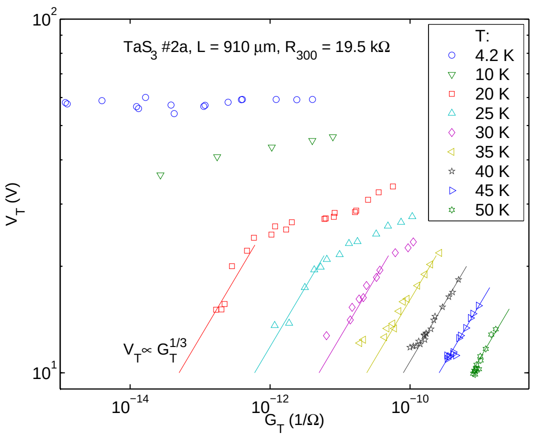
Change of carrier concentration will change the screening of CDW deformation and affect collective phenomena, such as:

- E_T
- CDW creep
- Nonlinear conduction
- CDW metastable states
- Dielectric constant ε

Growth of the threshold field under illumination



Conduction-dependent threshold field



Small fields
$V_T \lessapprox 20$ V

$E_T \propto G_T^{1/3}$

Large fields
$V_T \gtrapprox 20$ V

E_T approaches to temperature-independent behavior at $T \rightarrow 0$

Light-induced change of the elastic modulus of the CDW

1D pinning

$E_T \approx \left(\frac{n_i w}{K_{||}}\right)^{1/3}$, where n_i — impurity concentration, w — pinning potential, $K_{||}$ — elastic modulus of the CDW

Elastic modulus as a function of the current currier concentration

$K_{||} \propto \frac{q}{n}$ [Artemenko, Kruglov, JETP (1982)]

Expectation

$E_T \propto n^{\frac{1}{3}}$, in agreement with experiment

CDW deformation contribution into linear conduction

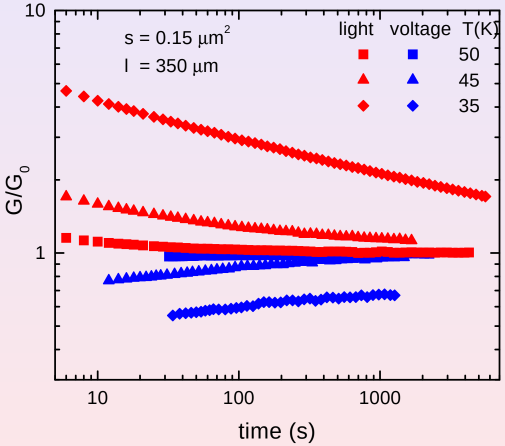
Question

Is there an effect of illumination on the CDW state?

Method of testing

Create nonequilibrium CDW state and to check its relaxation

Conduction relaxation after applicaton of a voltage pulse



Illumination effect on dielectric constant

Expectation

$\varepsilon \propto 1/E_T \Rightarrow$ illumination will decrease ε

Experimental difficulty

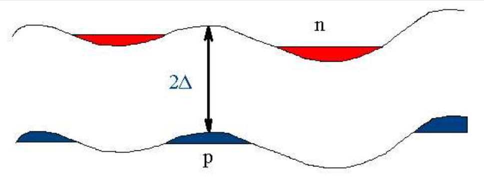
Thin crystals — small currents, difficult to measure qualitatively

Our observtion (qualititative)

Illumination *increases* ε

Our understanding

Pinned CDW creates a potential relief



There is a spatial separation of photoexcited electrons and holes in the potential relief created by pinned CDW

Outline

Conclusions

- We observed photoconduction in the Peierls conductor TaS_3
- It is demonstrated that low-temperature photoconduction and linear conduction are provided by different physical mechanisms
- Illumination result in change of the CDW state and affect a number of collective effect such as E_T, ε, metastable states, CDW creep rate
- Illumination-induced changes of E_T can be accounted in the frame of existing theories giving $E_T \propto G^{1/3}$