ESRF	**Experiment title: Dynamical depinning and charge transfer between CDWs in $NbSe_3$**	**Experiment number**: HS1919
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Report:

$NbSe_3$ is the prototype of a class of charge-density-wave (CDW) systems exhibiting collective transport phenomena [1]. A CDW consists of a periodic lattice distortion coupled to a modulation of the conduction electron density, of same periodicity. Application of an electric field above a finite threshold value, *unpins* the CDW and gives rise to collective electron transport.

The unit cell of $NbSe_3$ is formed of 3 pairs of metallic chains running along the monoclinic b-axis [2]. Below T_{P1} = 145 K, a CDW appears on one pair of chains with a wavevector $\mathbf{Q_1}$=(0, 0.241,0), followed by a second CDW transition on a second pair of chains, with T_{P2} = 59 K and $\mathbf{Q_2}$ = (0.5, 0.260, 0.5).

Preliminary measurements below T_{P2}, when both sets of CDWs coexist, have yielded a very unexpected result, namely a non-polarised shift along **b*** of both $\mathbf{Q_1}$ and $\mathbf{Q_2}$, above a threshold current value, about 10 times larger than the current value I_{C2} required to unpin the lower CDW Q_2. This *non-polarised* distortion (i.e. same shift for opposite current polarities) indicates the occurrence of a *charge transfer* between the two sets of CDWs, a phenomenon totally unexpected up to this point.

The aim of the present proposal was to obtain more detailed information on this new effect, using high-resolution X-ray diffraction and *in situ* electrical measurements.

Fig. 1 shows the longitudinal Q_1- and Q_2-satellite profiles vs. normalized current, I/I_{C2}, at T = 50 K for sample I. The depinning of Q_2 occurs at I_{C2} = 0.1 mA. Opposite Q_1- and Q_2-satellite shifts are observed for $|I/I_{C2}| > 9$.

Fig. 2a shows the broad band noise (BBN) signal generated by the CDW sliding motion at T = 50 K together with the differential resistance dV/dI as a function of applied current, on the same sample. A first jump in

BBN signal occurs at I_{C2}, as evidenced by the concomitant sharp drop in dV/dI. A second increase in BBN occurs at $|I/I_{C2}| \sim 9$, i.e. at the current value where the simultaneous shifts of the Q_1- and Q_2-satellite positions develop. We identify this second threshold current as the threshold current I_{C1} for depinning of Q_1.

Fig. 2b shows the temperature dependence of the threshold fields E_{C1} and E_{C2}, in the temperature range 40 K< T < 100 K. The increase of E_{C1} on cooling abruptly stops near T_{C2}, which gives evidence for some degree of dynamical interaction between the two waves.

The combination of high-resolution X-ray diffraction and transport measurements have revealed a variation of the Fermi surface dimensions associated with the Q_1- and Q_2-CDWs, when both CDWs are set in motion. This effect can be viewed as a sliding-induced charge transfer between the coexisting Q_1- and Q_2- condensates (see attached manuscript, submitted to Phys. Rev. Lett.).

The present experiments were limited to the 45 K-50 K temperature range, i.e. above the range where hysteretic depinning (*switching* effects) is observed [3]. There is probably a close connection between the Q_1-depinning threshold at E_{C1} and the switching threshold E_T*. More detailed diffraction and transport studies, in the switching regime (T < 40 K) are required in order to clarify the link between the switching effects seen in transport measurements and the satellite shifts revealed by high-resolution X-ray diffraction.

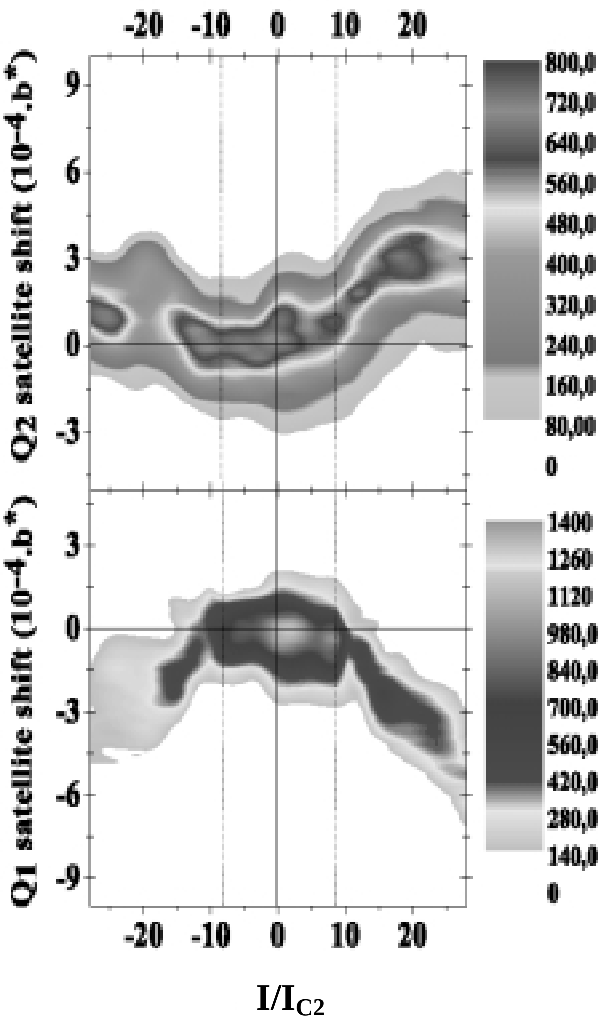
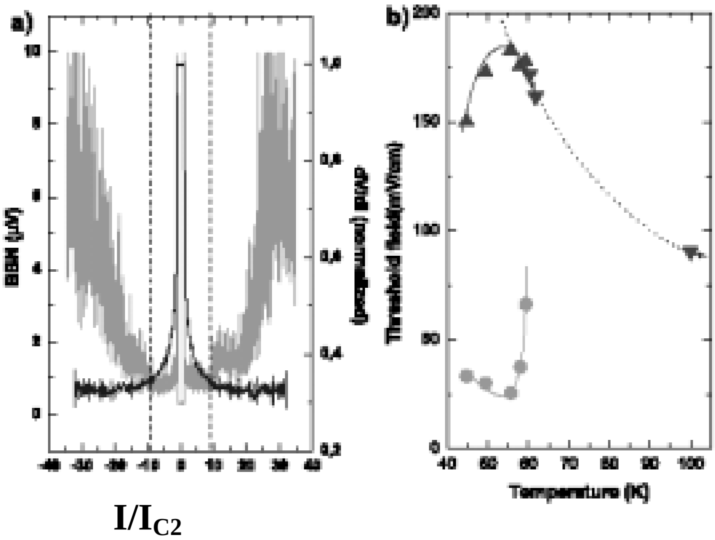


Fig. 1: Longitudinal Q_1 (bottom) and Q_2 (top) satellite profiles vs. applied current, normalized to the treshold current I_{C2} (T=45K, sample I). The origin on the vertical scale coincides with the unshifted (zero-current) peak centre and the two vertical dotted lines mark the position of the upper threshold current, I_{C1}

Fig. 2: (a) Broad Band Noise (BBN) (orange curve) and normalized differential resistance dV/dI (blue curve) vs. normalized current; the dashed lines indicate I_{C1} (T=50K; sample I). (b) Temperature variation of the threshold field for depinning of Q_1 (E_{C1}: ▼ from dV/dI, ▲ from BBN) and Q_2 (E_{C2}: ● from dV/dI).



[1] G. Grüner, Rev. Mod. Phys, **60**, 1129 (1988).

[2] J.L. Hodeau et al. J. Phys. C **11**, 4117 (1978).

[3] Y. Li, D. Y. Noh, J. H. Price, K. L. Ringland, J. D. Brock, S. G. Lemay, K. Cicak, R. E. Thorne and M. Sutton, Phys. Rev. B, **63**, 041103(R) (2001).