ESRF	**Experiment title:** High resolution study of the phase coherence in sliding charge-density-waves	**Experiment number**: HS1271
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Report:

The charge density wave (CDW) ground state of the quasi-one-dimensional compound $NbSe_3$ below the Peierls transition temperature T_P = 145K, is characterized by a periodic modulation of the lattice ionic positions accompanied by a modulation of the electronic density with the same periodicity. Application of an electric field above a finite threshold value unpins the CDW and gives rise to a collective electron transport: $J_{cdw} = nev$, with v the CDW drift velocity. The velocity of the sliding condensate is limited by the rate of conversion between normal and condensed carriers near the contact electrodes. This conversion is mediated by phase slip processes (see Expt. Report HS 961). The purpose of the present experiment was twofold:

1 - to enhance the phase coherence of the sliding CDW using the so-called mode-locking technique
2 - to study a model phase slip center by injecting an additional current in the central part of the sample.

Since the experiment has been performed at the beginning of February, the results are not fully analysed and this report is only preliminary.

Due to the presence of a distribution of domains with different velocities, the CDW transverse coherence length is strongly reduced during motion, while its longitudinal coherence is slightly improved (motional reordering). In a diffraction experiment this is seen as a dramatic transverse broadening of the satellite reflections. When both dc and ac electric fields are applied simultaneously, the Current-Voltage I-V characteristic exhibits Shapiro steps due to interference or phase locking of the internal CDW frequency $\nu_o = v/\lambda_{cdw}$ (or one of its harmonics and subharmonics $\nu_o p/q$; p,q=integers) with the external applied frequency. In figure 1 we have drawn the variation of the differential resistance dV/dI of a 3mm-long $NbSe_3$ sample (sample 1) at T=120K as a function of the applied dc current I when a 5MHz rf voltage of 150mV is superposed on the dc current. The dc threshold field to unpin the CDW is strongly reduced and peaks in the dV/dI spectrum indicates mode-locking for rational *p/q* values. The peak at $I/I_t \approx 3$ corresponds to the fundamental mode locking (*p/q*=1). On the same figure is plotted the width of the satellite profile in the chain direction (longitudinal width) for several dc current values. It is clearly seen that the rf field *decreases* the width of the satellite and that the reduction is maximum at the fundamental mode-lock position. The effect should be even clearer after the data are deconvolved for instrumental broadening. On the other hand, the transverse profile broadening in the sliding state is *not reduced* by application of the rf field. Thus, this experiment demonstrates that the action of the rf field is to improve the synchronisation of the '*in series*' CDW domains and to reduce the phase slip rate at the domain interfaces normal to the metallic chains.

In the second experiment, we have measured the CDW deformation profiles in the vicinity of closely spaced electrodes placed in the central part of the sample (sample 2). The insets in fig. 2 show the experimental set-up. A current, *I*=0.4mA, above the threshold value (I_{th} =0.15mA) is injected between electrodes A and B. Electrodes C and D are 2µm-wide and non-perturbative in the sense that they do not distort the CDW. Then an additional current, *i*, is injected through electrodes C and D. CDW coherence is broken at these electrodes and phase slippage occurs in order to accommodate the difference in CDW velocities between segments (AC, DB) and segment CD. We have measured the deformation, *q*, induced by this phase slippage at a position located 20µm away from the electrode D, using a 30µm-wide X-ray beam. When the currents *I* and *i* have the same polarity ($i > 0$), the deformation increases with *i* and saturates at large *i* values. When *I* and *i* have opposite polarities ($i < 0$), the CDW motion in segment CD is first slowed down until it becomes pinned for –0.6 mA< *i* <-0.4 mA, as indicated by in situ electrical measurements. For *i* < -0.6 mA the CDW motion in segment CD is inverted with respect to its motion in the remainder of the sample. A surprising result shown in fig.2 concerns the regime –0.6 mA< *i* <-0.4 mA : although the measurements are made at a position very near the electrode D, i.e. at the interface between the pinned CDW in segment CD and the mobile CDW in segment DB, the CDW deformation is found to be negligible in that regime. This result is not fully understood at the moment and will require further investigation.

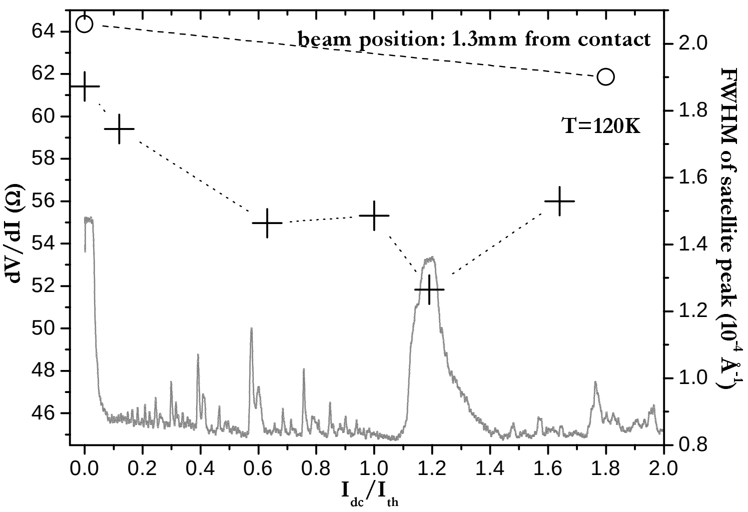

Figure 1. : Longitudinal width of the CDW satellite as a function of applied dc current, without (circles) and with (crosses) 150 mV rf field. The continuous curve shows the sample's differential resistance *dV/dI*, measured in situ, with spikes corresponding to the mode-lock regimes (Shapiro steps). $NbSe_3$, sample 1, *T*= 120 K.

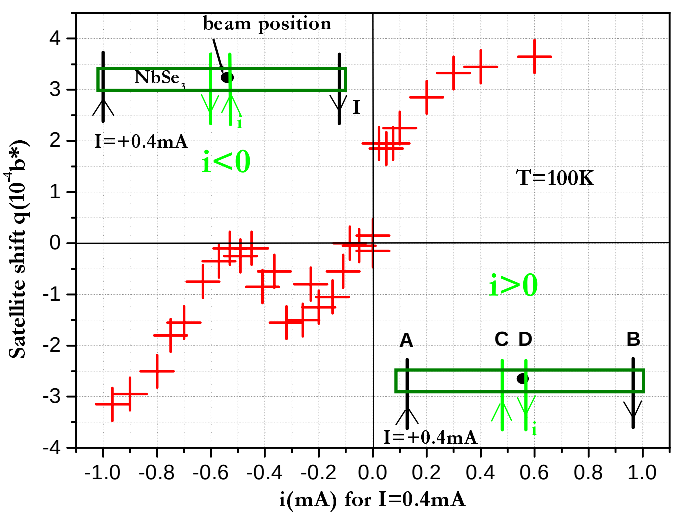

Figure 2. : CDW deformation near a non-perturbative electrode (D) as a function of applied current *i* between C and D electrodes, for a fixed value of the current *I* between A and B. $NbSe_3$, sample 2, *T*= 120 K.