Spatiotemporal properties of exciton-polariton dynamic wave-packets in periodic acoustic potentials

Edgar A. Cerda-Mendez

Paul Drude Institut, Hausvogteiplatz 5-7, Berlin, Germany

Purpose of the visit

The visit aimed to the realization of experimental work to study the properties of exciton-polariton dynamic wavepackets (solitons and triggered optical parametric oscillators -TOPO) subjected to an acoustically generated periodic potential. During the visit we expect to observe the effects of modulation on the wavepacket during its propagation parallel and perpendicular to the acoustic wavefronts. The experiments are of exploratory character in the sense that they are the first of its kind and we expect a variety of novel effects to be observed. We expect these studies to give us a general overview in order to plan more detailed and specific studies in the future.

Description of the work carried out during the visit

A GaAs-based microcavity was used for the studies. The surface acoustic waves (SAWs) are generated using metallic interdigitated transducers (IDTs) deposited at the surface of the

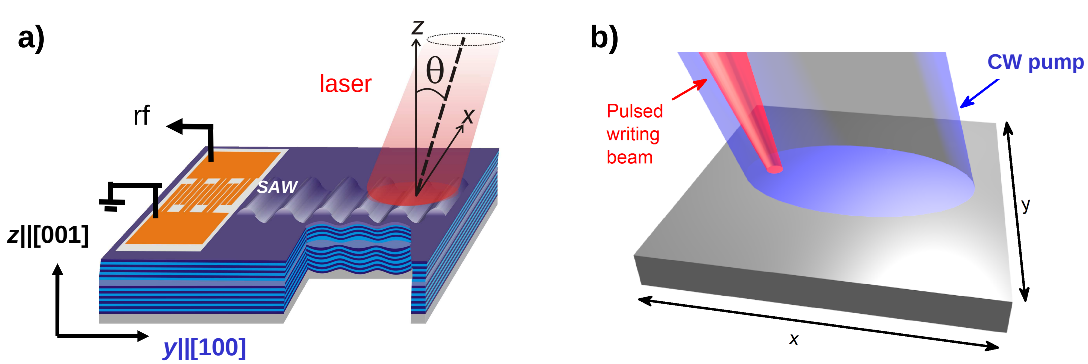

Figure 1: a) Scheme of the sample, where the IDT at the surface generates a SAW that propagates along a [100] direction. b) Polariton wavepacket excitation technique. The CW pump has a diameter of around 60 μm and the writing beam of 5 μm.

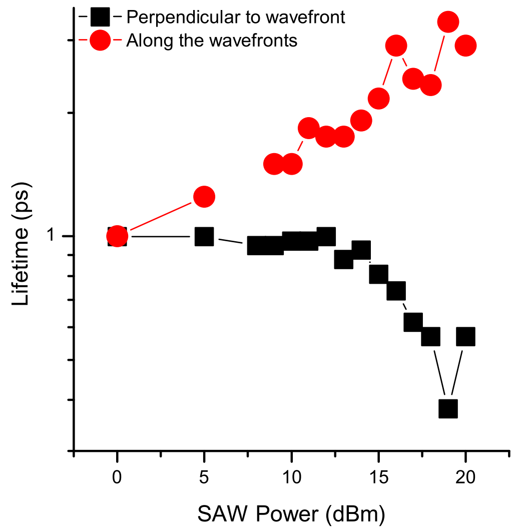

Figure 2: Normalized wavepacket propagation length (defined as distance at which the wavepacket polariton density is equal to $1/e$ the initial value) when the wavepacket propagates perpendicular (black squares) and parallel (red circled) to the SAW wavefront.

sample (cf. Fig. 1a). The SAWs have a wavelenght of $l_{SAW} = 8$ μm and a velocity $v_{SAW} = 2.6$ μm/ns. The sample contains two IDTs oriented along <100> directions perpendicular to each other. The generation of the wavepackets was made using a resonant pump-probe optical excitation technique. The pump is a single mode CW laser of 60 um diameter and the probe is a small diameter (5 um) ultrafast laser pulse (5 ps), as illustrated in Fig 1b. The conditions of generation of the wavepackets were changed by varying the probe laser intensity and incidence angle. The photoluminescence (PL) emission was spatially resolved and captured by a Hamamatsu streak camera with temporal resolution of 2 ps installed on a spectrometer.

Description of the main results obtained

Propagation along and perpendicular to the SAW wavefronts

The propagation of a soliton wavepacket in the SAW periodic potential was difficult to establish. Although under certain circumstances we were able to trigger the soliton, it was too unstable to be able to obtain a fully consistent set of data. We attribute this to the reduced bistability of the polaritons under the SAW potential. We do not discard however the possibility to excite solitons in the periodic potential. The following results were therefore performed in the triggered optical parametric oscillator (TOPO) regime, where a polariton wavepacket propagates on top of a condensate.

The behavior of the TOPO wavepacket propagating along SAW wave front and perpendicularly to wavefront are shown on Fig. 2. When a wavepacket propagates along SAW wave front (red dots) we observe an increase in its lifetime propagation length with high SAW powers, which can be attributed to two processes: 1) with SAW on, amplification due to parametric scattering becomes more efficient; 2) wavepackets propagating along the wave

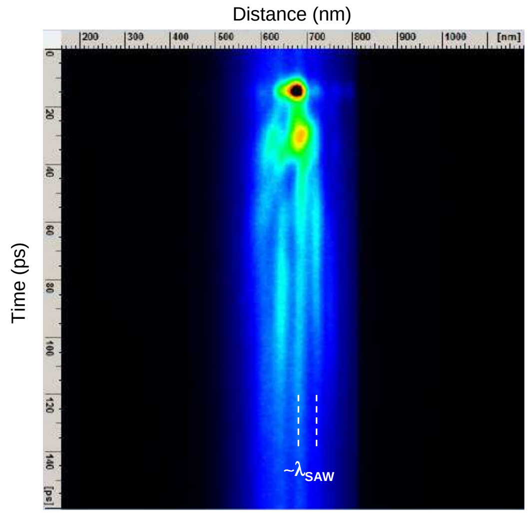

Figure 3: Branching of the wavepacket excited at low k-vector. Some oscillatory behaviour can be seen in the beginning. Distance between 'branches' approximately the same as SAW wavelength.

front are confined by the SAW potential and spread less, hence they maintain high density for longer times. When the wavepacket is propagating perpendicular to the SAW wave front, its lifetime decreases with increasing SAW power, since the potential barrier it has to overcome is higher. These wavepackets were resonantly excited by the probe of relatively high k-vector (of about 10 degrees incidence). The probe excitation angle (k-vectors of resonantly injected polaritons) is of critical importance for the system behavior when wave packet is propagating perpendicularly to the SAW wave front. We notice that the initial lieftime of the wavepackets propagating along and perpendicular to the SAWs were different, with values of 13 ps and 4 ps respectively. The difference in initial propagation length is due to the fact that the wavepackets were excited in different places on the sample, since different transducers were used.

"Branching" behavior

When the probe k-vector is below certain threshold level (approximately 5 degrees in our case), but is not 0, a different behaviour is observed. The probe propagates certain distance but in the meanwhile it breaks onto separated 'quasi-stationary' polariton populations that seem to reside in SAW potential dips, as shown in Fig. 3. 'Quasi-stationary' here refers to spatial positions of populations, which seem to be defined by the potential minima induced by the SAW. The minima are not strictly stationary since they are moving with the SAW group velocity v_{SAW} which is negligible on a picosecond timescale. Some oscillatory behaviour was also observed, especially at the beginning of this 'branching' process.

Conclusions

The polariton wavepackets generated under the SAW potential present a complex behavior that seems to depend critically on the conditions of excitation, in particular, of the incidence angle of the probe. Two very different behaviors were observed. At large probe k-vector, the propagation of the wavepacket increases (decreases) when it propagates along (perpendicular to) the SAW wavefronts. This behavior is more or less expected, however a more systematic study which includes, for example, polarization properties, is required to get a comprehensive picture. In the case of small probe k-vector, the behavior is rather unexpected, as a spatially fix periodic pattern with the periodicity of the SAW forms, in spite of the moving character of the SAW. This behavior is interesting and its full understanding requires a deep analysis which would include experiments varying the size of the probe beam, for example.

Future collaboration with host institution (if applicable)

In view of the results shown in this report, it is not possible to draw a definite conclusion on the behavior of the system without realising more experimens. We expect therefore to continue the close collaboration in the near future with the group in Sheffield in order to gather more experimental data and provide an adequate model explaining our results.

Projected publications/articles resulting or to result from your grant

The propagation of polariton wavepackets in periodic potentials is a rather unexplored field. We expect that a our results provide data novel enough to be published in a high impact journal. Among these results, we expect to obtain data regarding the formation of solitons, temporal evolution of wavepackets in the periodic potential and phenomena resulting from the screening of the SAW potential due to a larger population of polaritons in the minima of the potential.

Other comments (if any)

We expect to apply for a second POLATOM grant in the near future to complete our studies.