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Supporting information for article:

Quantification of propagating and standing surface acoustic waves by stroboscopic X-ray photoemission electron microscopy

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S1. Detection of working IDTs inside the PEEM sample stage

Due to the limited high frequency connectivity of the microscope sample stage, the SAW transmission cannot be directly measured by electrical means when inside the PEEM sample stage. Figure S1 shows the typical response of a working IDT that can be obtained from the sample inside the sample stage by a Network Analyzer (Agilent E-5071B) directly connected to the coaxial cables (i.e., with the high voltage rack off and open). The reflected RF signal (s_{11}) shows an overall slow modulation (due to the reflection at the UHV feedthrough) and considerable damping (due to the long cable, which also protects the RF amplifier from reflected power). Only the fast oscillation of s_{11} at around 125 MHz is the signature of the connected IDT; neither a visible dip in the insertion loss or a transmission peak could be observed.
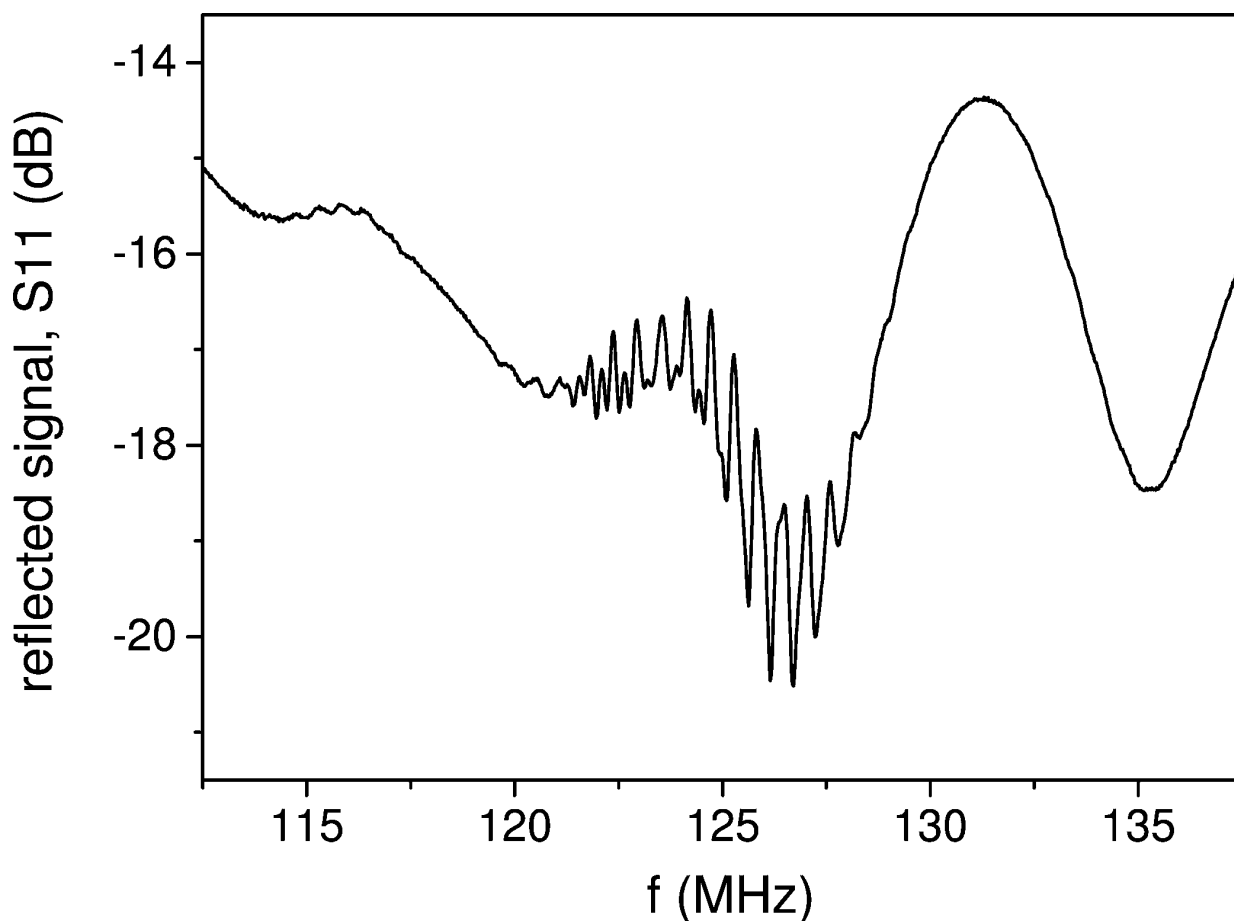

Figure S1   Characteristic reflection feature of a connected IDT in the PEEM sample stage measured with a network analyser.

S2. (Video S1) Time dependent pattern of a 500 MHz propagating and standing SAW for a slightly detuned excitation signal with respect to the synchrotron bunches.

(Video description) Time dependent pattern of a 500 MHz propagating and standing SAW for a slightly detuned excitation signal with respect to the synchrotron bunches. Using a small, deliberate detuning of the SAW excitation with respect to the synchrotron repetition rate, characteristic beat like patterns can be observed. The video shows the 500 MHz SAW as time dependent stroboscopic XPEEM images for two different situations: in the left panel, images acquired with only one IDT excited are shown, while on the right, two opposing IDT are excited with equal amplitude, resulting in a dominantly propagating or standing SAW respectively. Here the detuning is $\Delta f \approx 0.1$ Hz, resulting in a period of 10 s for a complete phase scan or beat pattern. Each frame in the video is spaced by 0.1 s in time, so that one period corresponds to 100 frames (total video length 200 frames). This data is analysed in more detail by pixelwise FFT, as explained in the main text and shown in Fig. 4.

S3. Interactive applet to plot propagating and standing SAW patterns from two IDTs

The HTML application presents an interactive model for the generation and quantification of a standing wave created from a pair of IDT. We consider two waves excited by the IDT located one in front of the other, similar to the experimental setup, having different amplitudes. We also consider the corresponding reflections with a phase shift associated to the distance between the IDT with respect to the wavelength. The two waves s_1 and s_2 can be written as follows:

$s_1 = A \exp[-ikx+i\omega t]+rA \exp[ik(x-2L)+i\omega t]$

$s_2 = B \exp[ik(x-L)+i(\omega t-\varphi)]+rB \exp[ik(L-x)+i(\omega t-\varphi)]$,

where A and B are the amplitude of the two waves with wavenumber $k=2\pi/\lambda$, L is the distance between the two IDT, r is the reflection coefficient for the wave at each IDT, and φ is the relative phase. We plot in the HTML application the amplitude of the resulting wave as a function of the x-position (for $x = 0$ to $x = 2\lambda$).

We introduced in the application four sliders for the following parameters:

Amplitude bias: We considered that total amplitude of the addition of the two waves is always 1, i.e. $A + B = 1$, and this parameter just tells you how much of each wave is excited.

-100% means there is only s_1, 0% means there is the same amount of s_1 and s_2, and 100% means there is only s_2

Relative Position: This is the parameter L that derives from the distance D between the IDT as in $L = D \bmod \lambda$. We include variations of this parameter between 0 and 1.

Reflection: The IDT create a reflection of the incoming wave with certain attenuation; we consider values between 0 and 1 (1 means full reflection)

Relative phase: The two waves can have an initial phase difference that is controlled by this parameter, φ, varying between 0 and 360^0

There are two parameters that are fixed in the experiment, relative position and reflection, which are related with the distance between the IDT and the reflected power of the waves. On the other hand, amplitude bias and relative phase can be changed in the experiment.

At the bottom of the graph we list the r-value and the propagating and standing wave amplitude for the selected parameters. The buttons on the top-left are preselected situation (preselected parameters).

S4. (Video S2) Standing SAW observed in continuous MEM-LEEM mode

Imaging with incident electrons is only sensitive to standing SAW because it is a continuous source. The standing SAW at 500 MHz is generated by exciting two opposing IDT structures. During the video, the relative phase between the two excitation signals is changed, showing how node and antinode position can be controlled at will.