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Time-Resolved Visualization and Quantitative Estimation of Ferroelectric Polymer Fiber Motility using Wavelets

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Introduction

This poster presentation considers the applicability of time-resolved scanning electron microscopy methods (including stroboscopic scanning electron microscopy, time-resolved environmental scanning electron microscopy and time-resolved atmospheric scanning electron microscopy) with real-time correlation spectral analysis using QAVIS software (based on the FFTW library) developed at POI FEB RAS [1-5] for measuring the mobility of ferroelectric microfibers under the electric field or under the influence of a particle beam using the FIB-SEM technique or a conventional SEM electron beam.

Long periods of monitoring require expression of the fiber mobility in time through some kind of mathematical processing, from which it is possible to calculate reactivity, polarizability, conversion coefficients (for a given field in the direct and reverse piezoelectric effect in ferroelectric fibers, especially in the case of a low quality factor typical for some polymers), dependence of microelectromechanical dynamics on the signal parameters, etc. Thus, we need some "descriptors" as compact heuristically valuable representations of time-resolved experimental data.

We propose to use complex wavelet approaches for this purpose. Unlike the real-valued Morlet wavelets, complex versions are referred to as Gabor wavelets. This type of wavelets was developed by Dennis Gabor in 1946 based on the extrapolation of the main ideas from quantum physics into the field of signal processing (because from 1930s, such functions were used in quantum mechanics, where they were referred to as Weyl-Heisenberg functions). Later their applications arose, taking into account the Heisenberg uncertainty principle in time-series analysis with Gabor atoms. Gabor proposed using sinusoids with a Gaussian window for time-frequency decomposition, which he has called "atoms" and which provided a compromise between spatial and frequency resolution.

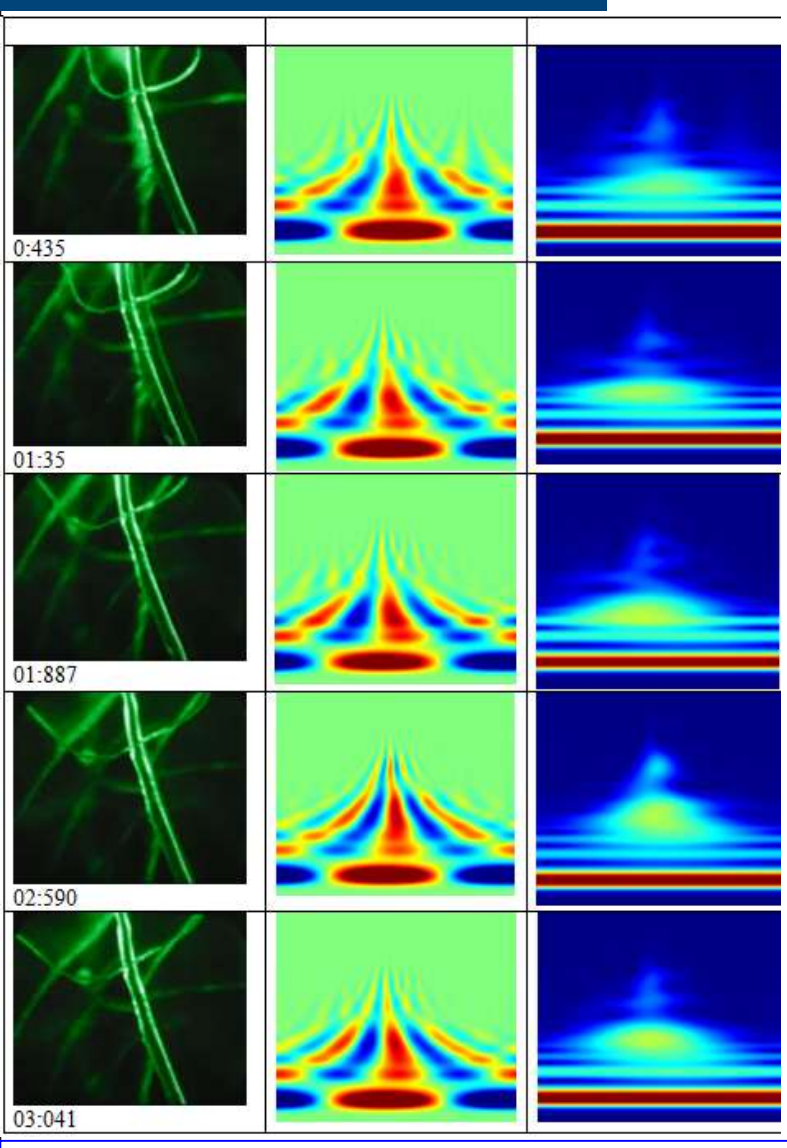
In facts, Gabor "atoms" are modulated Gaussians, so their mathematically implementation is not so difficult. If a Gaussian is used as a window in the theory of communication, then the values of the windowed Fourier transform exactly coincide with the signal

Methods

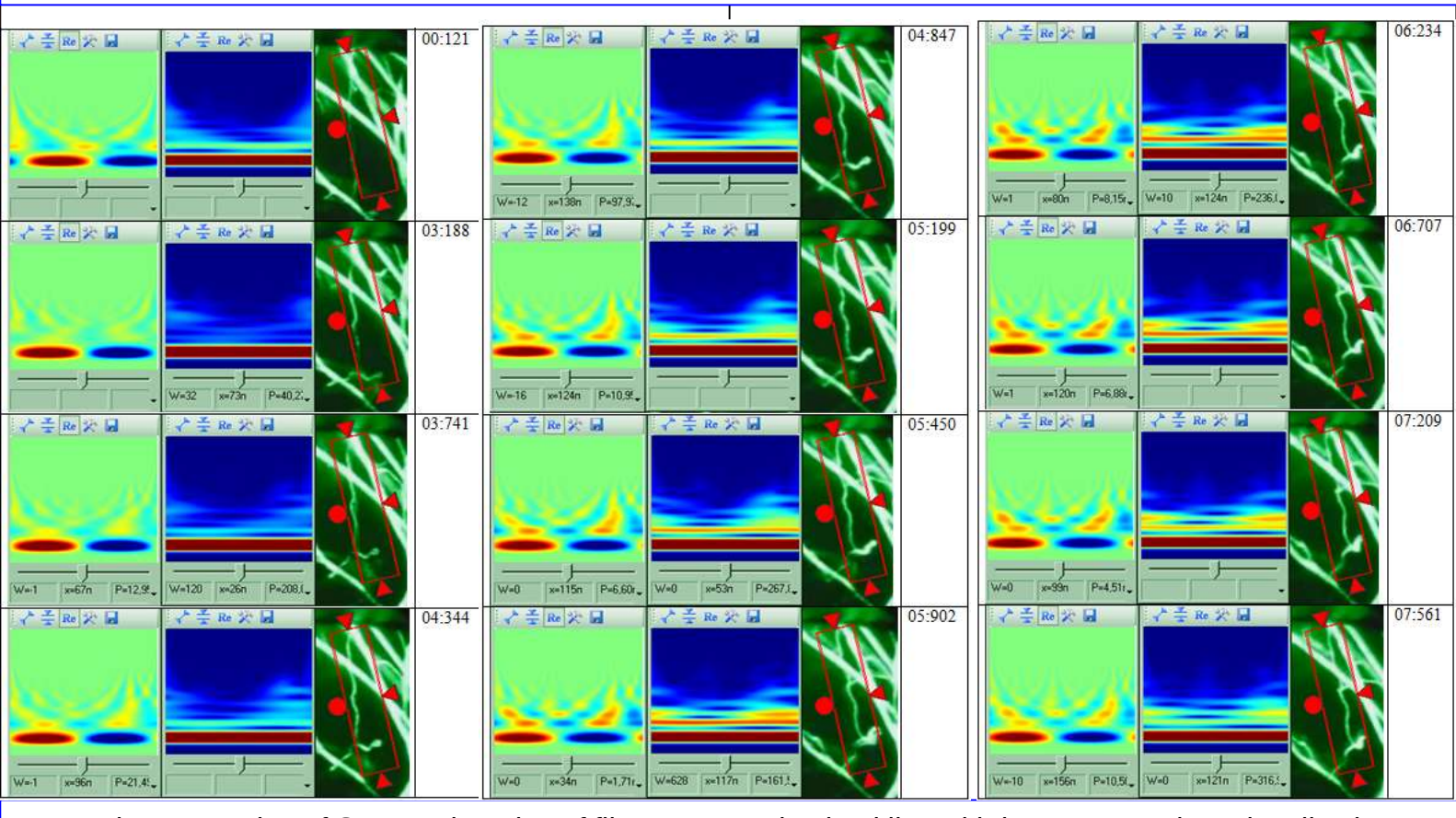
The analysis was carried out either in real time during digitization or later from the video recordings using QAVIS software developed at POI FEB RAS by A.A. Goncharova and V.K. Fishchenko [1-5]).

Time-resolved SEM studies of the ferroelectric [6-12] PHB scaffold fiber dynamics were performed by JEOL JSM T330-A scanning electron microscope with the image (and time-lapse / videostream) acquisition systems developed by O.V. Gradov and P.L. Alexandrov.

Results



Wavelet processing of SEM registrations of single dielectric charged fiber dynamics: Re and Im visualizations.



Wavelet processing of SEM registration of fiber construction buckling with knots: Re and Im visualizations.

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