Improved Ultrafast Digital Lock-In Amplifier for High Speed Atomic Force Microscopy

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High Speed Atomic Force Microscopes (HS-AFMs) are new and exciting tools for watching biomolecules in action [1]. The HS-AFM technique offers three orders of magnitude higher frame rate than the classical instruments while its resolution and capability to operate in liquid environment remains unchanged. Such high frame rates were achieved as a result of exhaustive analysis of each component of the microscope and their optimization for higher imaging bandwidth [2].

For intermittent-contact mode, which is nearly exclusively used for biological AFM imaging, replacement of long classical cantilevers with short and thin cantilevers was one of the most important modifications. These new cantilevers have about 10-50 times higher resonance frequency. Consequently, these cantilevers are potentially 10-50 faster than the classical ones. To exploit this quick response time of these new cantilevers, it is necessary to determine their oscillation amplitude and phase from one cycle while keeping the signal to noise ratio as high as possible.

We presented such an ultrafast lock-in amplifier at last year conference. Our device used the Fourier method to calculate the amplitude and phase of every single cycle of oscillation [3]. Now we present further enhancement and acceleration to the device. To achieve high signal to noise ratio, we remarkably oversample the cantilever signal using high resolution (16 bit) analog-digital converter and the result is averaged. In the updated version the oversampling ratio is automatically adjusted to the operating frequency guaranteeing the best possible signal to noise ratio at lower frequencies. In addition, the operation frequency range has been extended from 10 kHz up to 5 MHz. Our device can be adapted to every high speed or classical AFM and it offers flexible operation frequency range.

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