Spectral resolution of an ultrafast microwave spectrum analyzer based on a sweep-tuned spin-torque nano-oscillator

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Modern applications in radar and communication technologies often use frequency-agile signals, the spectral analysis of which requires sub-μs temporal resolution. Such a speed of the spectral analysis can be achieved with a sweep-tuned spectrum analyzer only if the local oscillator of the analyzer has a nano-scale size, and very low time constants, so that its frequency can be swept on the time scale of the targeted temporal resolution. It was predicted in [1, 2] that such an ultrafast analysis can be performed using spin-torque nano-oscillators (STNO) both in microwave (MHz to GHz) [1] and THz [2] frequency ranges.

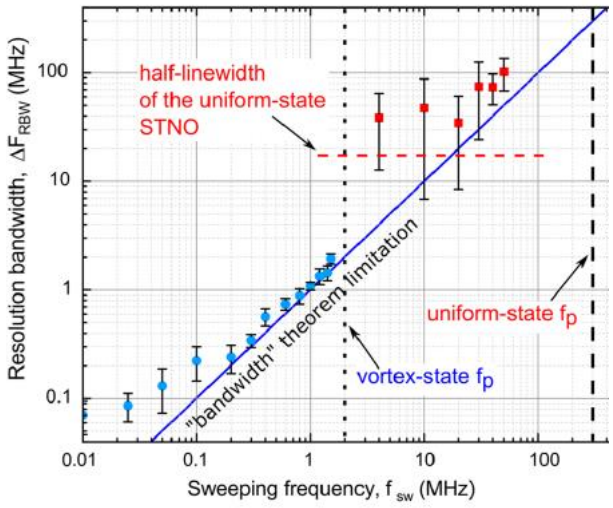

Fig.1 Resolution bandwidth of a sweep-tuned spectrum analyzer as a function of the sweeping frequency.

Recent experimental studies [3, 4] performed on the vortex-magnetic-state [3] and uniform-magnetic-state [4] STNOs, rapidly sweep-tuned by a bias voltage, fully confirmed these theoretical predictions, and proved that ultrafast time-resolved spectral analysis of frequency-agile microwave signals is possible. The critical reduction in the time of the spectral analysis comes from the naturally small (1−100 ns) temporal constants of the nano-sized STNOs. The advantage of an ultrafast frequency-tunability of STNOs, that have a large (>100 MHz) relaxation frequency fp of amplitude fluctuations, is exploited to realize ultrafast wide-band time-resolved spectral analysis at nanosecond time scale with a frequency resolution limited only by the sweeping frequency through the “bandwidth” theorem (see Fig.1)

The demonstration of the time-resolved (T~50 ns) spectral analysis in the GHz frequency range (frequency interval of 1.0 GHz around a central frequency of 9.1 GHz with a scanning speed of 50 MHz/ns) was performed on an STNO comprised of a perpendicular polarizer and a perpendicularly and uniformly magnetized “free” magnetic layer [4]. It was shown in [4] that such a uniform-state STNO-based spectrum analyzer can efficiently perform spectral analysis of frequency-agile signals with rapidly varying frequency components, and that a relatively wide (~10 MHz) generation linewidth of the STNO does not significantly affect the frequency resolution of the spectral analysis, which is determined by the speed of the frequency sweeping.

[1] S. Louis et al., Appl. Phys. Lett. 113, 112401 (2018). / [2] P. Yu. Artemchuk et al., J. Appl. Phys. 127, 063905 (2020). / [3] A. Litvinenko et al., Nano Lett. 20, 6104 (2020). / [4] A. Litvinenko et al., Nano Lett., 22, 1874–1879 (2022).

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