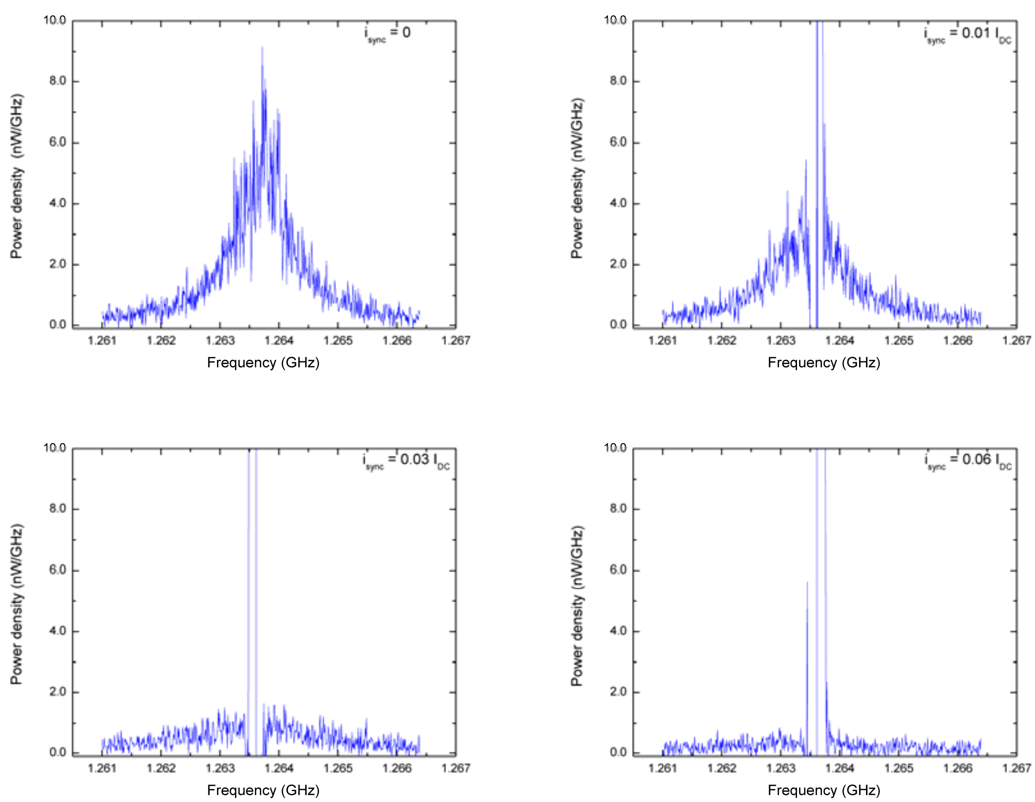
A. Locking efficiency

To learn more about the locking efficiency we performed additional electrical measurements. Representative results are shown below for a sample designed to be similar to the sample for which the x ray measurements were performed (although this sample had a Py thin layer, as in Ref. [6], rather than CoFeB). We applied a dc current (I_{DC} = 16.5 mA) and varying strengths of ac current, and used a frequency-domain technique (similar to Rippard *et al. PRL* 95, 067203 (2005) and Georges *et al. PRL* 101, 017201 (2008)) to measure the microwave signal emitted by the resonator near the resonance frequency. The ac drive signal at 1.2635 GHz cannot be completely cancelled, so we cannot measure directly the amplitude of the phase-locked oscillator signal, but we can measure the unlocked portion of the signal by observing the microwave power emitted outside the narrow linewidth of the externally-applied signal. In the absence of any ac current, there is of course no injection locking and the natural linewidth of this spin-torque oscillator is about 1 MHz. For an ac current I_{sync} = 0.01 I_{DC}, the power in the wings of the spin-torque resonance is slightly reduced but the overall linewidth is similar, indicating that for such a small ac current injection locking is not completely effective. However, for I_{sync} = 0.03 I_{DC} and I_{sync} = 0.06 I_{DC} the unlocked background signal is reduced nearly to zero. From this we are confident that the value of I_{sync} used for our x ray imaging (I_{sync} = 0.07 I_{DC}) is sufficient for approximately 100% efficient injection locking.



In addition, we note that even if the injection locking were not 100% efficient, so that the spin-torque oscillator fluctuated between periods of locking and periods without locking, this should act only to reduce our signal strength (the contrast in our images) but it should not change the radius that we measure for the vortex motion.

B. Thin layer

Below are two images of the thin magnetic layer, measured on similar samples, showing the absence of any detectable out-of-plane component of the magnetization or non-uniform in-plane magnetization in this layer. The images were obtained by tuning to the Co absorption edge, which allows us to look at the thin layer alone. Both images have lateral dimensions of 400 nm x 400 nm. Dotted lines show the approximate shape of the devices. The left image displays the dichroic signal measured with the beam perpendicular to the sample and shows the absence of any out-of-plane component of the magnetization down to the noise level. The right image displays the dichroic signal measured with the beam inclined at 30 degrees from the normal (the maximum possible tilt). The signal in this image originates only from the in-plane component (since the left image shows there is no perpendicular component). Therefore, the uniform white region indicates that the measured in-plane component is approximately uniform. (Note that the left image is plotted using a smaller range for the gray scales to maximize contrast and emphasize that no magnetic signal is visible.)