# Optimization of the Spin-Torque Oscillator for Microwave-Assisted Magnetic Recording via Response Surface Methodology

**Kheong Sann CHAN[1], Yasushi KANAI[2], Ryo ITAGAKI[2] and Susanto RAHARDJA[3]**

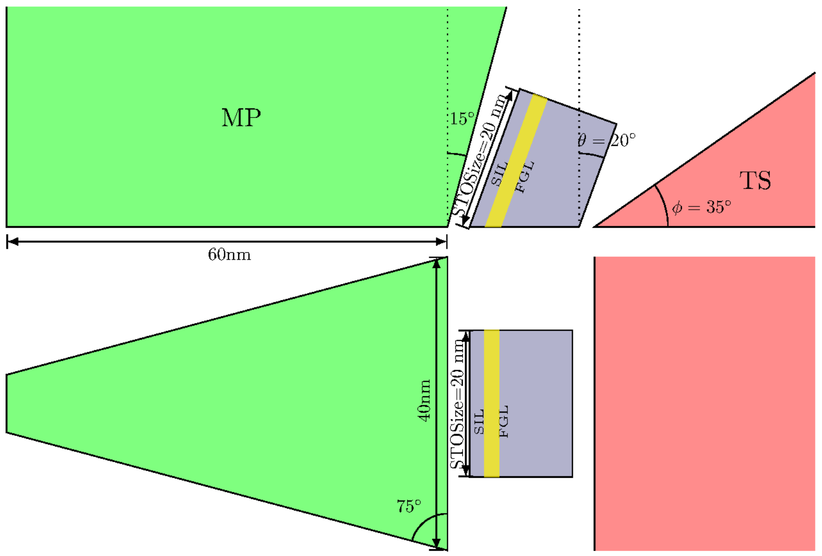
1) Nanjing Institute of Technology, Nanjing, China, chanks@njit.edu.cn

2) Niigata Institute of Technology, kanai@iee.niit.ac.jp

3) Northwestern Polytechnical University, susanto@nwpu.edu.cn

## Introduction

Microwave Assisted Magnetic Recording (MAMR) [1] is a new technology for magnetic recording that has the potential to help continue the areal density growth trend that the industry has historically experienced in the past. MAMR uses the principle of the resonance of the magnetic grains in the medium to an applied microwave frequency field to bring down the required switching field of the grains during writing. In MAMR, the microwave frequency assisting field is generated by a spin-torque oscillator (STO) [2, 3] that is placed in the gap between the main pole (MP) and the trailing shield (TS) as shown in Figure 1. However the STO is subjected to external magnetic fields from the main-pole and also from the medium which impacts on the stability of its rotation. It is of interest to select the STO parameters to give the most stable output rotation performance. In the current work we attempt an optimization search over 4 STO parameters shown in Figure 1 using design of experiment (DoE) methods and the response surface methodology (RSM).




| Parameter 1<br>STO Tilt Angle | |
|---|---|
| Symbol | $\theta$ |
| Unit | deg |
| Nominal value | 20 |
| Step | 6 |
| **Parameter 2<br>Trailing shield angle** | |
| Symbol | $\phi$ |
| Unit | deg |
| Nominal value | 35 |
| Step | 8 |
| **Parameter 3<br>STO size** | |
| Symbol | STOSize |
| Unit | nm |
| Nominal value | 20 |
| Step | 5 |
| **Parameter 4<br>Current Density** | |
| Symbol | $J$ |
| Unit | A/cm$^2$ |
| Nominal value | 4.5e8 |
| Step | 1.5e8 |

Figure 1: Geometry of the MP, STO and TS. The STO is tilted at an angle $\theta$ while $\phi$ is the angle of the TS. The STOSize is the third optimization parameter and the current density $J$ is the fourth. FGL - Field Generating Layer. SIL - Spin Injecting Layer.

## Methodology

There are many parameters that can impact the STO performance and multi-parameter optimization over a large number of variables is a challenging undertaking. In the current work, we optimize a narrowed down choice of parameters that are deemed important to the STO performance. Previously the authors in [2] found that tilting the STO at an angle $\theta$ can lead to more stable STO rotation. They also introduced variation in the trailing shield angle $\phi$ to mitigate its magneto-static impact on the STO. In addition, two important parameters that impact the STO performance are the STO dimension (STOSize) and the current density ($J$). These make up the 4 control parameters that we have chosen to optimize in the current study.

The optimization is performed through micromagnetic simulations, with judicious choices for the values of the above mentioned control parameters. The observed AC field ($H_{AC}$) at the surface of the medium at a point below the STO is computed through micromagnetic simulations and it is the oscillation properties of this field that we seek to optimize. A sample micromag output is shown in Figure 2. The micromagnetic simulations of the STO include the impact of both the magnetic fields from the writer and from the soft underlayer (SUL) of a double-layered medium in this work.

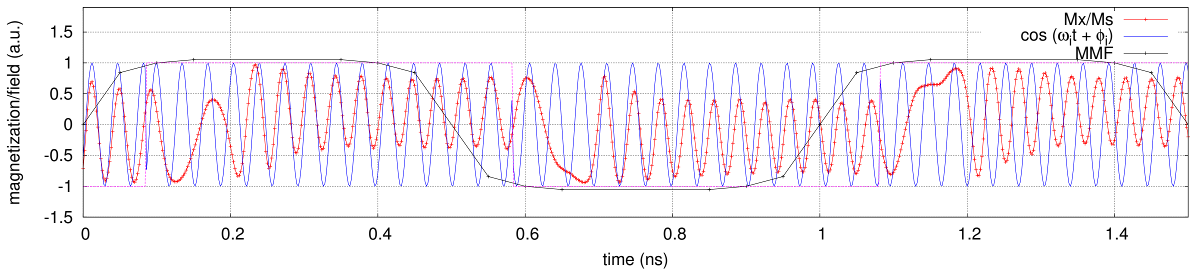



Figure 2: Oscillation of the FGL magnetization shown in red. The write field from the MP is shown in black. An ideal sinusoid with parameters $\omega_i$ and $\phi_i$ is shown in blue.

To obtain our cost-function parameter we align an ideal sinusoid (shown in blue) of the form $\cos(\omega_i t + \phi_i)$ to the FGL oscillation. Our DoE search will attempt to maximize the correlation between the ideal sinusoid and the oscillation of the FGL field. The parameters of ($\theta$, $\phi$, STOSize, $J$) that optimize this cost function will be searched for using the response surface methodology (RSM). A list of the parameters used that are held constant in this work are shown in Table I.

Table I: The non-varying parameters used in our micromagnetic simulation optimization.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **STO Parameters** | | | | | | | |
| | $4\pi M_s$ | $H_k$ | $\alpha$ | Exchange A | thickness | Polarization Factor | Interlayer Thickness |
| FGL | 20 kG | 31.4 Oe | 0.02 | 2.5e-6 erg/cm | 10 nm | | |
| SIL | 6 kG | 31.4 Oe | 0.02 | 0.75e-6 erg/cm | 2 nm | 0.5 | 2 nm |
| **Main Pole Parameters** | | | | | | | |
| MP Angle | | MP width | MP-TS gap | $4\pi M_s$ | $H_k$ | Exchange A | $\alpha$ |
| 15° | | 40 nm | 20 nm | 24 kG | 31.4 Oe | 3e-6 erg/cm | 0.2 |
| **SS Parameters** | | | | **TS Parameters** | | | |
| MP-SS | $4\pi M_s$ | $H_k$ | $\alpha$ | MP-TS | $4\pi M_s$ | $H_k$ | $\alpha$ |
| 60 nm | 15 kG | 50.2 Oe | 0.2 | 20 nm | 15 kG | 50.2 Oe | 0.2 |

## References


[1] J. G. Zhu, X. Zhu and Y. Tang, "Microwave Assisted Magnetic Recording", *IEEE Trans. Magn.*, 44(1) 125-131, (2008).

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[3] H. Sepeheri-Amin, S. Bosu, C. Abert, Y. Sakuraba, S. Kasai, M. Hayashi, D. Suess, and K. Hono, "Design And Development Of Spin-Torque-Oscillator For Microwave Assisted Magnetic Recording", *TMRC 2017*, presentation E2.