Spintronics Research at ARL

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Army Need:

- High frequency, low operating voltage communications for networked autonomous microsystems
- Remote sensing for system health monitoring & biomimetic navigation
- High Sensitivity, low cost sensors
- Improved non-volatile memory

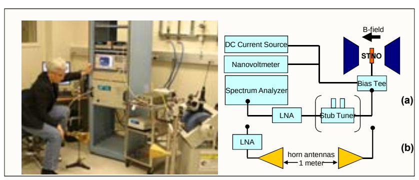
Approaches:

- Spin torque nano oscillators (STNOs) - current-controlled devices with GHz-THz frequency response modulated by applied drive current *and* by external magnetic field.
- MEMS flux concentrator
- Spin transfer torque (STT) RAM

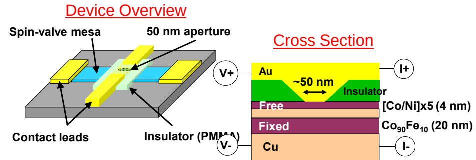
ARL Experimental Infrastructure:

- Class 10/100 nano/microfabrication facility
- Programmable electromagnet with ±1.5T field
- Spectrum analysis/signal generation to 110 GHz
- Cryogenic probes to 5K/50GHz
- Phase noise & frequency stability analysis
- High resolution/ high speed time domain digitizers for RF waveform analysis in time/frequency domain
- Arbitrary waveform generators for complex waveform modulation and analysis

Experimental Infrastructure

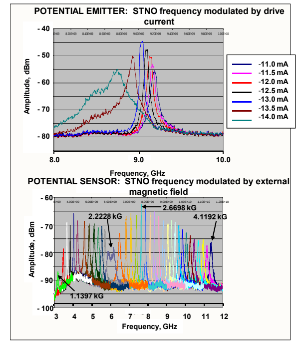


STNO Device Overview

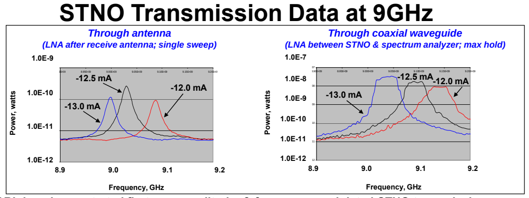


Advantages:
- Planar fabrication on silicon substrate
- Room temperature operation at voltages < 0.25V

RF Output Frequency Modulation



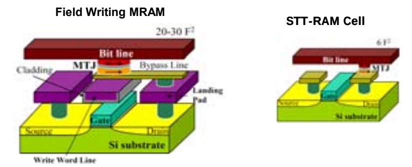
STNO Transmission Data at 9GHz



- ARL has demonstrated first ever amplitude- & frequency-modulated STNO transmission:
  - 9 GHz, 250 pW signal transmitted through air over a distance of 1 meter
  - STNO demonstrated as a non-reactive, real resistance 12.5Ω device, broadband over 4 octaves of frequency (from *at least* 500 MHz – 10 GHz *range of test conditions*)
- ➢CHALLENGE: Phase noise (above, right) attributed in part to discontinuities within STNO "free layer" thin film heterostructure (< 1nm metal layers)

STT RAM Small

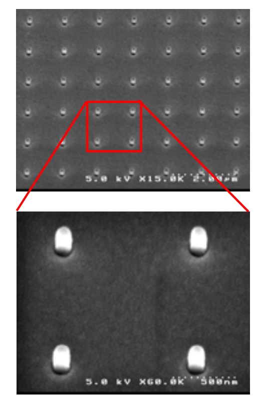
NVM having fast speeds and unlimited endurances



Advantages of STT RAM Ring Shaped Devices

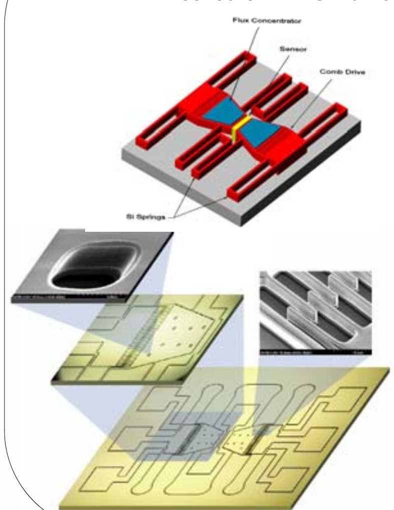
- Much smaller write current: $I_{c0} = \frac{2\alpha A M_s t_F e}{\eta \hbar}\left[H_K + \frac{H_d}{2}\right]$ $H_K = H_{intrisic} + H_{shape} + ...$
- More thermal stability
- Smaller cell size, MTJ 1 F²
- Transition less chaotic, leads to narrower write current distribution

SEM of ARL pillars



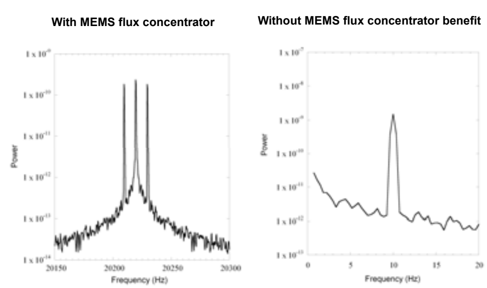
Before using vapor HF to undercut the Si

Solution to 1/f noise problem in small magnetic sensors: MEMS Flux Concentrator



- MEMS flaps with flux concentrators oscillate in plane
- Field largest when they are closest to sensor
- Field smallest when they are furthest from sensor
- Modulates the field at kilo Hertz frequencies
- Operating frequency of sensor shifted to higher frequency
- Required combining MEMS & magnetic sensor technology
- Achieved using two chips & flip chip bonding

Data showing the Benefit from MEMS Flux Concentrator at 10 Hz



15X Improvement in power spectrum

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