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# Solid-state Electromagnetic Drive

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# A solid-state drive for an MSM micropump

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## I. Background/objective

We have developed a solid-state electromagnetic drive for BSU's breakthrough MSM micropump. Electromagnetic coils substitute permanent magnets to apply a magnetic field to a magnetic shape memory alloy (MSMA) element, resulting in a new crystallographic twin variant. These deformations manifest in the MSMA element as regions of shrinkage, which can be used to transport a small volume of liquid if the location of the shrinkage is moved.

## II. Simulation and construction

- LTspice to model control circuit and FEMM to model behavior of magnetic flux
- Three coils wrapped around iron core, with MSMA element positioned above coil assembly
- Magnetic field concentrated above one of two pole pieces; we control which pole is active by changing current flow through coils
- We use an Arduino microcontroller to control switching of semiconductor devices

## III. Results

- We have reliable control of position and intensity of magnetic field
- Flux density of 0.5 Tesla possible above active pole
- The magnetic field is sufficient to cause shrinkage
- We make shrinkage above one pole disappear and reappear above the other pole

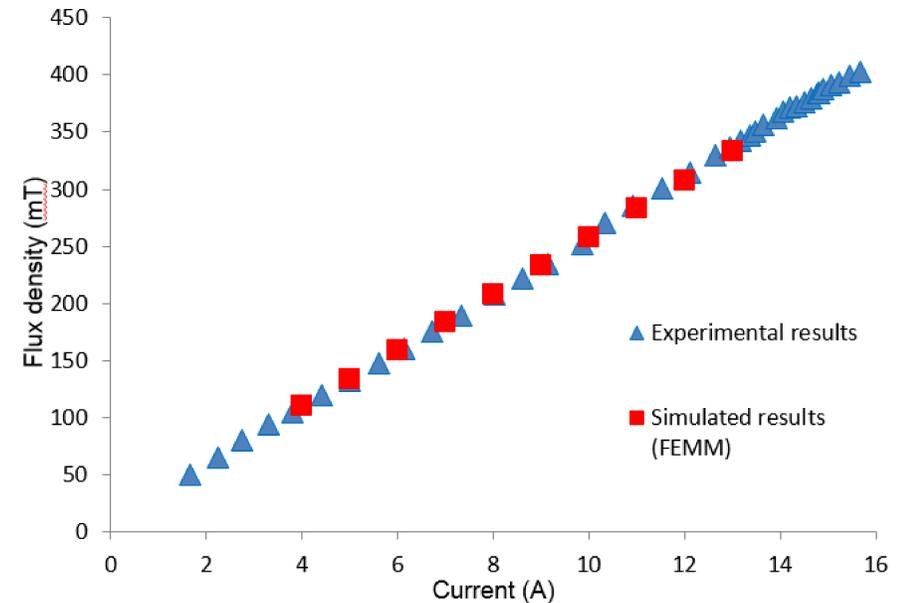


Fig. 6. Simulated and experimental magnetic flux density as a function of coil current

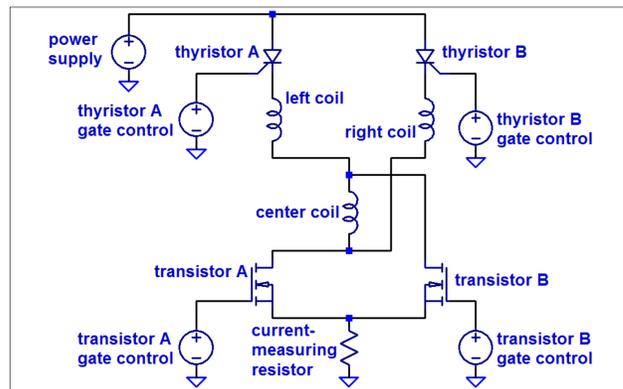


Fig. 3. LTspice schematic showing power supply, control circuit, semiconductor devices, and coils

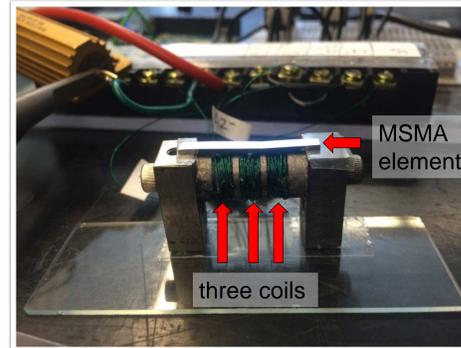
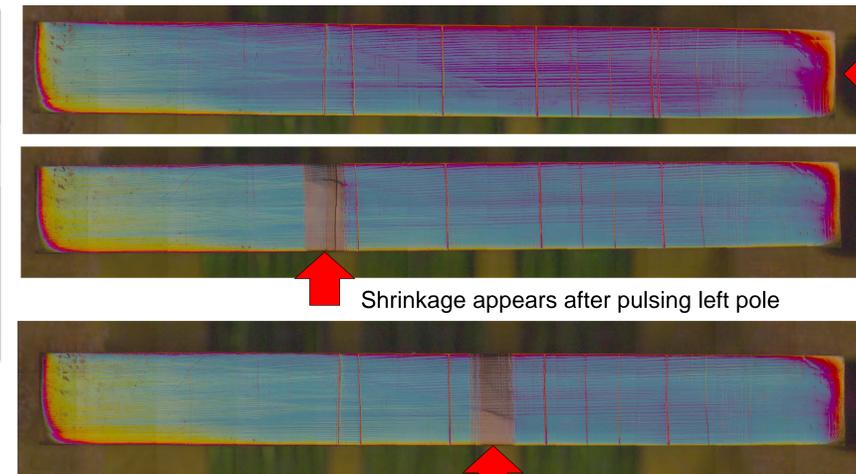


Fig. 5. Image of coils, ferromagnetic assembly, and 27-mm-long MSMA element



MSMA element before pulsing either pole

Shrinkage appears after pulsing left pole

Shrinkage changes position after pulsing right pole

Fig. 7. Differential interference contrast image showing MSMA element before pulsing, shrinkage after pulsing left pole, and new shrinkage after pulsing right pole. The ferromagnetic assembly and electromagnetic coils are visible in the background.

## IV. Conclusions

Our electrical circuit produces localized magnetic fields comparable to those of permanent magnets in the actuation of an MSMA element. We succeeded in causing twinning and forming shrinkages at specified locations in the MSMA element via magnetic flux pulses from the control circuit. We aim to increase the number of poles beyond two to further increase controllability of the position of the shrinkage in the element. We also aim to integrate the control circuit, coils, and MSMA element into a single printed circuit board at a later date.

## Acknowledgment

We thank Dr. Karthik Chinnathambi for assistance operating the Leica optical microscope. We thankfully acknowledge financial support through the NASA Idaho Space Grant Consortium and the Idaho State Board Higher Education Research Council under project IF16-003.

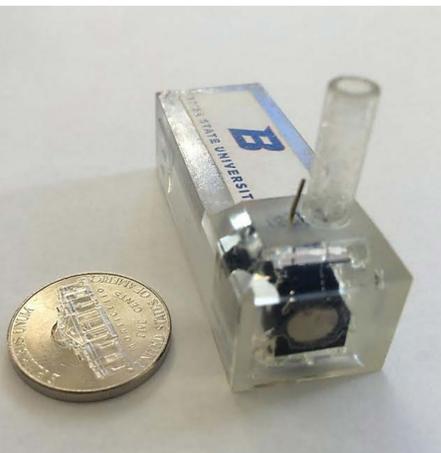


Fig. 1. BSU micropump used to inject ketamine to the subject rodent's hippocampus

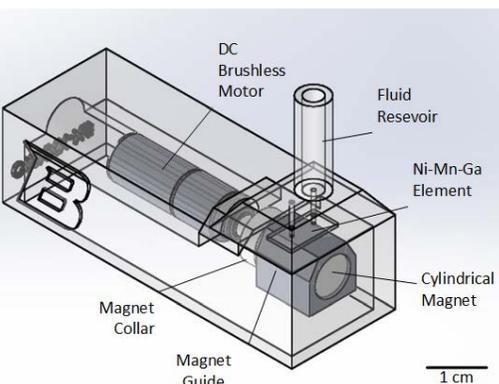


Fig. 2. Internal components of the permanent-magnet-actuated BSU micropump

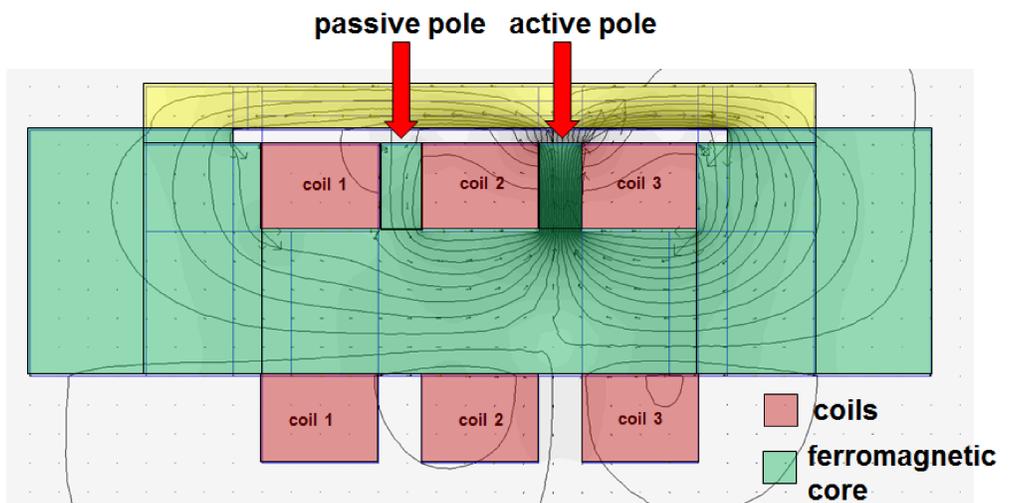


Fig. 4. FEMM simulation showing path of magnetic flux through MSMA element and iron core when coils 2 and 3 are active