Forecast:
Better times a-comin' ?

The Relaxation Times

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VOL.V NO. 10 | **NEWSLETTER OF TEACHSPIN, INC.** | **January 2021**

No doubt it's been a tumultuous year for you, as it has been for us. We hope this newsletter finds you healthy, and coping with all the pandemic-induced changes in your life and work. Here at TeachSpin we've adapted to work-from-home, and staggered-schedule methods, but we've been able to keep up with production and with customer service. We've even had some time to think, plan, and create some innovations.

Soon to be joining the TeachSpin team:
Dr. David Lee, Ph.D.

TeachSpin is delighted to announce that David Lee will be joining our staff in Buffalo this summer. We asked him to introduce himself to our readers and friends.

"I am excited to join Jonathan, David, and the rest of the Teachspin team as we navigate a new and somewhat uncertain higher-ed landscape. Even while big changes happen across the academy, the need for well-trained young physicists continues unabated. And while delivery of content, learning spaces, technological applications and even the hot research topics are always evolving, the preparation of a young physicist with firm grounding in the lab leaves her perfectly positioned to advance the state-of-the-art, whether in physics research or industry. Like so many of you, I have found the deepest learning and most meaningful experiences for students came out of advanced labs (and the follow-on mentored undergraduate research).

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Adiabatic Demagnetization
added to CMP experiments

You might recall that TeachSpin has developed the 'infrastructure' for a series of condensed-matter physics (CMP) experiments, consisting of a dewar, vacuum system, and supporting electronics, that enables your students to perform experiments in specific heat, magnetic susceptibility, electrical transport, and superconductivity. But now we announce a **fifth** experiment that fits into this CMP infrastructure, namely Adiabatic Demagnetization.

This experiment is a lovely marriage of magnetism and thermodynamics, and it illustrates a technique by which practical magnetic refrigeration can be accomplished. In fact, commercial cryogenic refrigerators offer cooling to below 50 mK using this technique. Our goals are more modest, but our experiment shows that cooling of a bulk sample by a few Kelvin can be explored. Students will rarely perform an experiment that makes a more direct appeal to *entropy* as an organizing concept.

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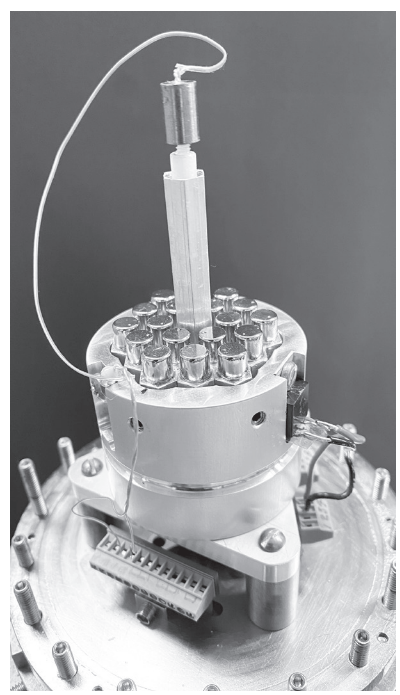


At top, a Gd sample on its push-rod, equipped with thermocouple, and pushed out of the magnet structure shown; at bottom, the temperature-controlled platform of our CMP dewar.

To help design, develop, and deliver advanced physics lab equipment to undergraduate physics majors around the world – rather than just those in the department at a small liberal arts college – is an exciting prospect. As I grew up in Western New York, this is also a return to home.

My career and research interests have largely been in the field of Materials Physics – mostly in metastable metal alloys. After finishing college (Engineering-Physics, Princeton) and graduate school (Applied Physics, Caltech), my post-doc was a NASA-funded project to study the thermophysical properties of undercooled liquids. These studies involved doing calorimetry on undercooled molten metal alloys using either TEMPUS (a microgravity-environment electromagnetic container, the successor to which is currently on ISS) or the ESL (electrostatic levitator, then located at JPL). While ESL experiments were complicated, they were far less so than the space shuttle flight experiments – and there was far less vomit involved in the testing (KC-135 flights were not my forté).

My first industry job involved working to scale-up production of a bulk metallic glass alloy discovered in our Caltech research group. The Zr-based alloy (dubbed Liquidmetal™) would eventually find its way into golf clubs, tennis rackets, missile fins, cell phone hinges and other applications. After that, I joined a startup called Symyx, which was doing combinatorial materials science some 15 years before it became all the rage at the funding agencies. My group ran 'combi' projects in phosphors, fuel-cell catalysts, magnetic, thermoelectric, spintronic, and metallic materials. While there I began to view so much of the interesting physics in materials as the physics of phase transitions. Phase transitions are such a universal concept, yet students get very little formal treatment on the topic in their undergraduate courses and almost no exposure to them experimentally. It is another reason I am so excited to join TeachSpin.

From Symyx I moved to another startup called Picoliter (later renamed LabCyte, and recently acquired by Beckman-Coulter). The technology involves using focused acoustic waves to eject droplets of liquid in a noncontact manner; a pulse of energy is delivered from a transducer coupled through the bottom of the container, typically a microwell plate; the meniscus bends upward until a droplet is ejected. These instruments are primarily used to mix minute quantities of fluids in pharma research, but also at the front end of a MALDI-TOF mass-spectrometer or anywhere one might require a tiny volume of fluid delivered precisely and without contact.

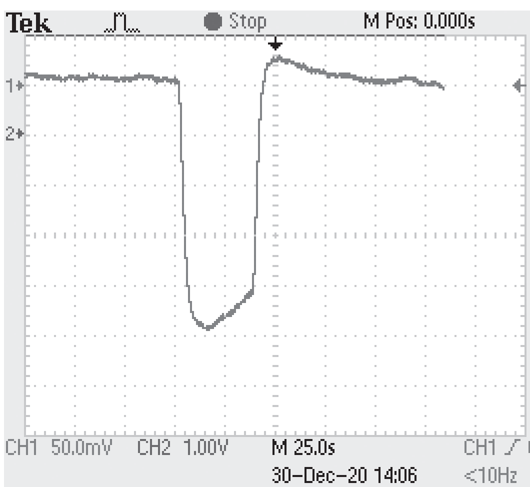
I rejoined academia in Fall 2003 at Gordon College (Wenham, MA), and have enjoyed mentoring undergraduate physics students as my wife Flora and I raised our now 17-year old daughter. While teaching, I was able to remain involved in the startup materials scene. In 2012, I took a year's leave to work at Glassimetal Technology, which is working to commercialize next-generation amorphous alloys, and a novel method for processing such alloys into applications such as orthodontics and electronics. Most recently, I have been working with Cambridge-based startup Kinalco to commercialize a new shape-memory alloy. Whether working to control a phase transition, such as with Kinalco, or avoid one completely, such as with a metallic glass, so many of the interesting (and useful) physical phenomena have their basis in an underlying phase transition. As with any novel technology, a deep understanding of the physics beneath it all is essential to making progress.

TeachSpin has so much great advanced lab equipment to help a student understand fundamental physics – and there is so much more that we can do and offer – it's an exciting time and I am grateful to be part of the team."

And we're excited that he'll be arriving. Here's hoping that you, our readers, will soon have the chance to meet David Lee as part of the team at an in-person conference, too!

This experiment takes advantage of the CMP dewar's temperature-controllable 'stage'. To that stage, we mount a special permanent-magnet structure that gives us a region of uniform magnetic field >0.9 T. We use our dewar's sample-manipulation capability to move a sample into, or out of, that magnetic field. We conduct the experiments in nitrogen, as a thermal-transfer gas. The built-in temperature servomechanism of the dewar chills both the magnet to a target temperature, and also the sample located inside the magnet. That gives us a sample that's magnetized and in its low-magnetic-entropy state. Now if the sample is pushed out of the high-field region, it demagnetizes, and its spin system acts like an 'entropy sponge'. The lattice entropy of the sample, and with it the bulk sample temperature, will drop.

We monitor the crucial temperature change of the sample, relative to the magnet, via a thermocouple.



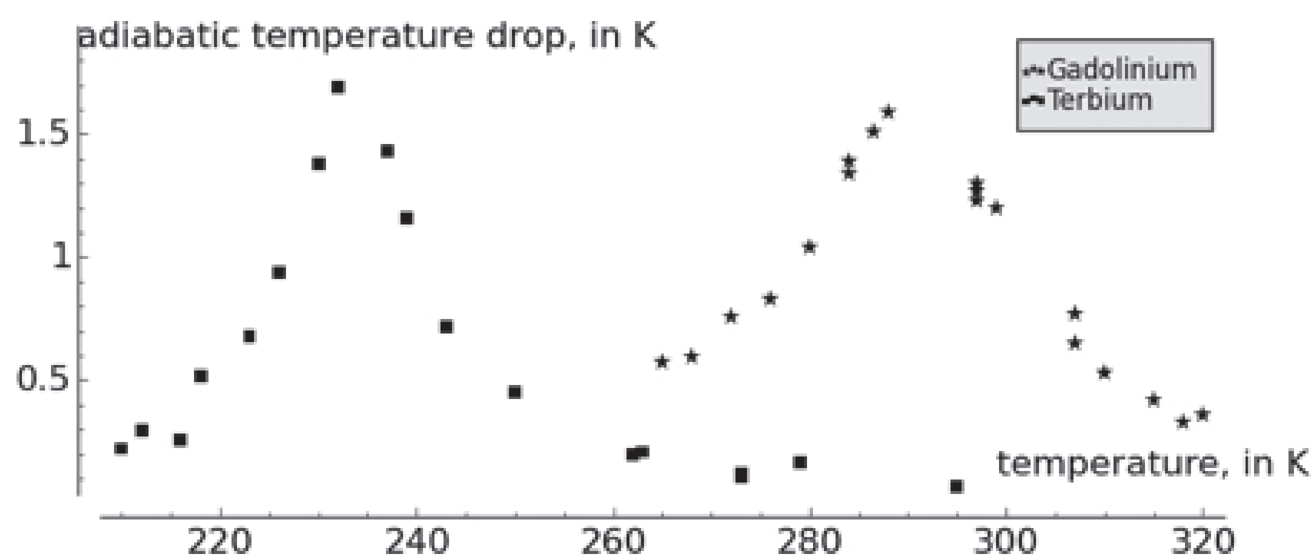
Thermocouple detection of a 1.3-K cooling of a Gd sample upon removal from a 0.9-T field at 297 K – note also the re-warming of the sample upon re-insertion into the field.

We take advantage of the fast response of the sample, and the thermocouple, to record the rapid magnetic cooling we observe.

We can, of course, also allow the sample to 'equilibrate to local temperature' while outside the magnet, and then see the 'magnetic heating' that results when its spins are driven adiabatically to a lower-entropy state upon inserting it into the high-field region.

Our CMP-AD experiment includes the high-field permanent-magnet structure we have developed, and a special Hall probe used to measure, and survey, its field. It includes samples of the rare-earth metals gadolinium (Gd) and terbium (Tb), as well as control-group samples of copper and aluminum. Each sample is equipped with a copper-constantan thermocouple for temperature measurement; TeachSpin's 'High Gain Utility Amplifier' maps the modest thermocouple voltage changes to easily-logged observable voltages. As always, a Manual provides guidance for students, and instruction in thinking in 'entropy space'. [For the benefit of CMP users who also have our Magnetic-Susceptibility experiment, we also include samples of Gd and Tb configured for use with that experiment.]

We show below some 'magnetic cooling' results obtained for Gd and Tb. The 'adiabatic temperature drop' observed upon removal from the field is plotted vertically, and is shown to depend on the starting temperature of the experiment. The results show dramatic and rather narrow peaks, whose location in temperature is directly related to the Curie temperature of these magnetizable rare-earth samples. The fact that Gd metal permits cooling in the vicinity of room temperature has not escaped the notice of innovators seeking to develop refrigeration technologies independent of 'greenhouse gases'.



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Inside:

Adiabatic Demagnetization
added to CMP experiments

TeachSpin celebrates an honor to our founder J. F. Reichert:

from a letter for Jonathan, arriving here in September 2020:

Dear Dr. Reichert:

It is my pleasure to inform you that you have been elected Fellow of the American Physical Society by the APS Council of Representatives at its September meeting upon the recommendation of the APS Forum on Education. The number of APS Fellows elected each year is limited to no more than one half of one percent of the membership. It is a prestigious recognition by your peers of your outstanding contributions to physics. The citation that will appear on your certificate is:

"for great contributions to hands-on advanced lab instruction, first as a professor for over three decades, then by initiating and supporting many vehicles for broad dissemination of teaching materials and equipment, directly impacting more than 85 percent of all physics degree-granting programs in the U.S."

Jonathan's response to this letter – "I would like to thank the APS for this honor, but I truly believe the honor belongs to the entire TeachSpin family that have worked so hard to create educational apparatus of the highest quality, as well as unique and competent technical support through our entire history."