Forecast:
'Scope for future improvement

The Relaxation Times

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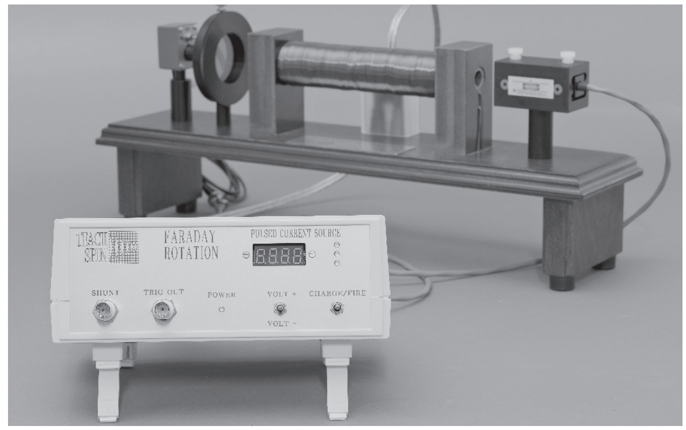
New Instruments, New Data

Whopping Faraday Rotations with our Pulsed Current Source



The March meeting of the APS marked the debut of our Pulsed Current Source (PCS), a tool for exciting the solenoid of our well-beloved Faraday Rotation apparatus with a unipolar pulse of current, exceeding >50 A in about 5 ms. This pulse easily respects the thermal dissipation limits of the solenoid, while creating internal fields >0.5 T and transient Faraday rotations in an SF-57 glass rod of >**45 degrees**. We showed you the diagnostic signals for current and field in our March 2025 Newsletter; here we wanted to present the *optical* signals that can be acquired using our new PCS.

Here's a first experiment easily performed by any user having our Faraday-Rotation apparatus. We suggest setting up the Faraday-rotation apparatus with its Polaroid analyzer set to the 'crossed' condition, so that no light comes through to fall on a viewing card. Now connecting the solenoid not to the usual dc power supply but to the PCS instead, one can initiate the sequence of a slow charging of the capacitor inside the PCS, followed by its fast discharge through the solenoid. No sparks fly, nothing audible emerges – but a visible flash of light does appear on that card. That's because the PCS really does create a brief but large Faraday rotation in the sample, so there will be a short interval (about 10 ms) when light encounters that analyzer *not* at the crossed angle.

And once you've seen that flash of light, you'll want to quantify it too, using the photodetector with which our Faraday Rotation apparatus is already equipped, and adding an oscilloscope to capture the transient. [Note that in order to acquire such data, students will necessarily learn how to use the PCS's trigger-output to trigger their 'scope, and thus learn the valuable technique of capturing one-time transient events.] Below is such a record from a 'scope, showing the measured current-shunt and transmitted-light waveforms, captured from one single pulse.

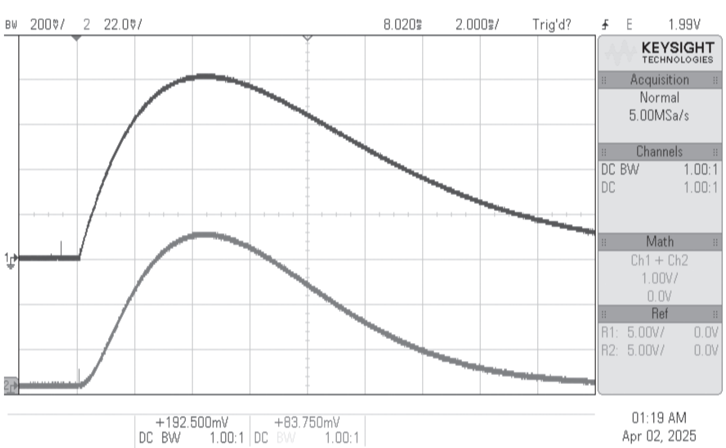


Fig. 1: Oscilloscope traces covering 20 ms of time. (Upper trace) The current-shunt output voltage, showing the waveform of the current *i(t)* during a single pulse. (Lower trace) The photodetector output voltage, showing the intensity of light falling on the detector, as the 'extinction condition' is evaded.

In this image, you can see the current reaches a peak value at about 4.5 ms after the start of the capacitor discharge. You can see that the potential developed across the built-in 22-mΩ shunt resistor reaches 0.81 V, indicating a peak current near 37 A. And in the lower trace, you see that the light-transmission level rises, from the 'extinction baseline', and reaches a peak that also is located at $t = 4.5$ ms, when the Faraday rotation reaches its largest value.

continued on p.2

To make quantitative modelling simpler, it pays to repeat these experiments when the Polaroid analyzer is set, not to extinction, but to an angle 45˚ away. Then in the absence of a current pulse, the light transmitted is not zero, but just half of what it would be for the analyzer set to the 90˚ or maximal-transmission angle. In the images below, that full-transmission reaches to the top of the screen, and zero light lies at the bottom of the screen. So the trace now lies at mid-screen height before (and after) the pulse. What happens *during* the pulse?

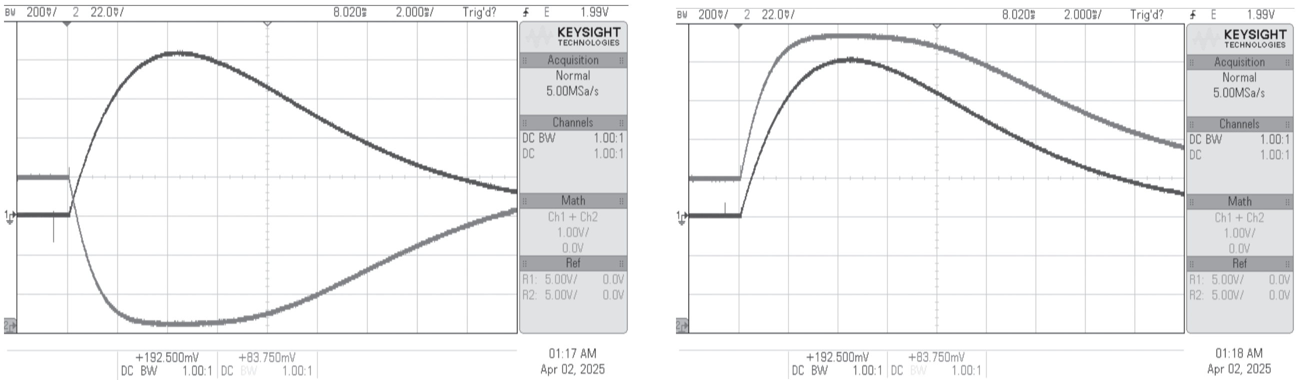


Fig. 2: (Ch. 1 traces) Again, the current-shunt output voltage. (Ch. 2 traces) The photodetector output voltage, showing the intensity of light reaching the detector, as functions of time. Horizontal scale is 2 ms/div; vertical scale for light-intensity ranges from zero light (at bottom) to full light (at top).

Clearly, the transmitted light falls, or rises, depending on whether the Faraday rotation during the pulse brings the emerging light's polarization closer to the extinction condition, or closer to the pass condition. In the left image above, we have the solenoid connected with the polarity that brings the transmitted light right down to the baseline (zero-light) condition. The image at the right was obtained under identical conditions, except for reversed connections of the PCS to the solenoid; it shows that temporary Faraday rotation can bring the light's polarization right up to the full-transmission level. The images together confirm that we can transiently achieve a full 45˚ of Faraday rotation, from a quiescent 45˚ angle to reach 0˚ and 90˚ in the two images above.

For a red-laser light source, we get this much Faraday rotation from a current pulse resulting from charging the capacitor to about 135 V (out of the 50 - 200 V range available). Hence you can easily achieve *more than* 45˚ of Faraday rotation, even for red light. If you have our 'green laser upgrade' for Faraday Rotation, you can dial up to create rotation angles >90˚!

Note the oddball nearly-flat bottom, and nearly-flat top, of the light-transmission signals in the data above. It's a worthwhile modelling exercise for students to use their *i(t)* data to predict *B(t)*, and to use their *B(t)* model, and the Law of Malus, to predict what transmission-history they ought to get in experiments such as these. Note too that the data above shows that rotation angles near 45˚ can be sustained for *several ms* around the time of peak current – this ought to motivate students to read, think, and experiment on the 'one-way transmission of light' that can be achieved when Faraday-rotation angles this large can be (transiently) attained.

TeachScope II and the 'FFT'

We've just re-introduced the TeachScope as a tool for helping students gain facility in using oscilloscopes to acquire, store, and display waveforms, and thereby build confidence and skills in using a 'scope as a routine diagnostic measuring tool. (Our experience in fielding service calls here at TeachSpin suggests to us that these skills are under-learned.) Recall the new TeachScope II allows a 'treasure hunt' among 16 available waveforms, on which students can test their 'scope skills. We can readily imagine students being assigned to capture images, or even data tables, of waveforms coming from a TeachScope II. Clearly they can be asked to recognize and interpret waveforms, and to measure amplitudes and frequencies, as exercises in 'scope-based capabilities.

But new to the TeachScope II are features motivated by the **frequency-domain** capabilities increasingly available even on educational 'scopes. If your 'scopes have an FFT = 'fast Fourier transform' button, our TeachScope II Manual can teach you how best to use it to get a view of an acquired waveform in the frequency domain, ie. as a plot of a spectrum, whose independent variable is not time, but *frequency*. Perhaps these FFT-capabilities will help motivate you to have your students make a 'second pass' of familiarization with a 'scope as a laboratory tool.

So we've put into the TeachScope II a number of waveforms whose content is best appreciated only when the signals are viewed in *both* the time and the frequency domains. Here's one of them, seen first in the time domain, in Fig. 3:

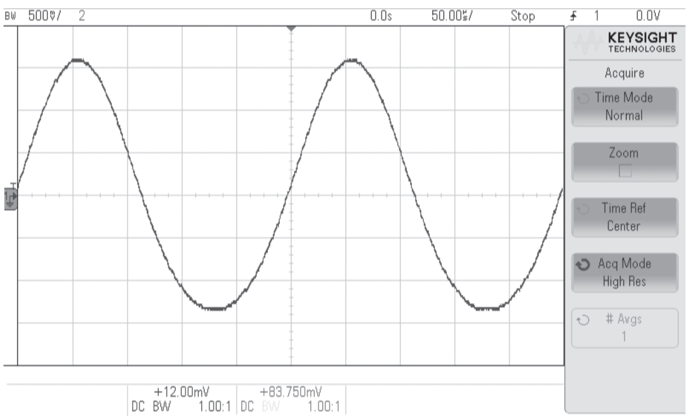


Fig. 3: One of the waveforms coming from a TeachScope II, viewed over 500 μs of time.

Most students will successfully see this as a periodic waveform of period 0.25 ms, and having peak-to-peak excursion of 2.9 V. Many students will call this a sinusoid; only those few audiophiles who've heard of 'harmonic distortion' will be attuned to note that in this waveform, the curvature of the peaks is sharper than that of the valleys. That suspicion can be confirmed by acquiring a Fourier spectrum of the same waveform, as seen in Fig. 4:

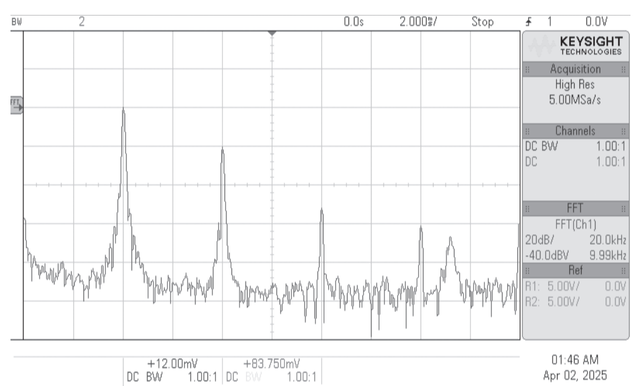


Fig. 4: The Fourier transform of the same waveform. Horizontal scale is linear in frequency, and extends from 0 to 20 kHz; vertical scale is logarithmic in spectral power, at 20 dB/division.

Sure enough, the spectrum shows a prominent peak at frequency $f = 4.0$ kHz, consistent with the period measurable from Fig. 3. But the spectrum also shows a distinct, though smaller, 'first overtone' or 'second harmonic' at frequency $2f = 8.0$ kHz (plus much weaker higher harmonics). The second harmonic is visibly '1 division down' or 'at -20 dB' relative to the fundamental; this tells an instructed user that it contains 10^{-2} of the power, hence has $10^{-1} = 0.1$ or 10% of the amplitude, of the fundamental. An interested student should also plot what a unit sine wave looks like when it's summed with a $2f$-component of one-tenth the fundamental's amplitude, to compare with Fig. 3's results. (What about *minus* one-tenth, ie. -0.1 times, the amplitude?)

And there are more gems rewarding frequency-domain detection hidden among the waveforms in the TeachScope II – which of your students will smoke out these mysteries first?

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Inside:

New data from two new instruments:
Pulsed-Current Source for Faraday Rotation and the **TeachScope II**

Quantum Control units available for *delivery from stock*

Consider attending a Faculty Workshop on

The Integration of Computation, Experiment, and Physics Theory (ConCEPT),

to be held June 4-7, 2025 at Gonzaga University

Two dozen faculty persons will assemble to develop modules useful to teaching faculty who wish to show students how the three pillars of physics (experiment, theory, and computation) work together in concrete cases to make phenomena understandable.

"We welcome applications from any and all physics faculty with an interest in innovative teaching practices — whether your strengths lie in theory, experiment, computation, or all three. Prior experience with integrated modules is not required — just a willingness to collaborate and contribute!"

For further information, see https://physics.csuchico.edu/~njnelson/ConCEPT-Call-for-Participants.pdf . Participants' lodging and travel costs are supported by the J. F. Reichert Foundation.

Job Posting for Experimental Physicist

TeachSpin Inc., an established designer, developer, manufacturer, and marketer of Advanced Laboratory Physics Instructional apparatus, is looking to hire an experimental physicist with experience in building physics apparatus. We're replacing the retiring founding CEO of 32 years, and seeking a candidate with long-term career aspirations. An MS in physics is required, but preference will be given to those with a PhD and having experience in teaching the Advanced Laboratory. Send resume and a cover letter to jfreichert@teachspin.com.