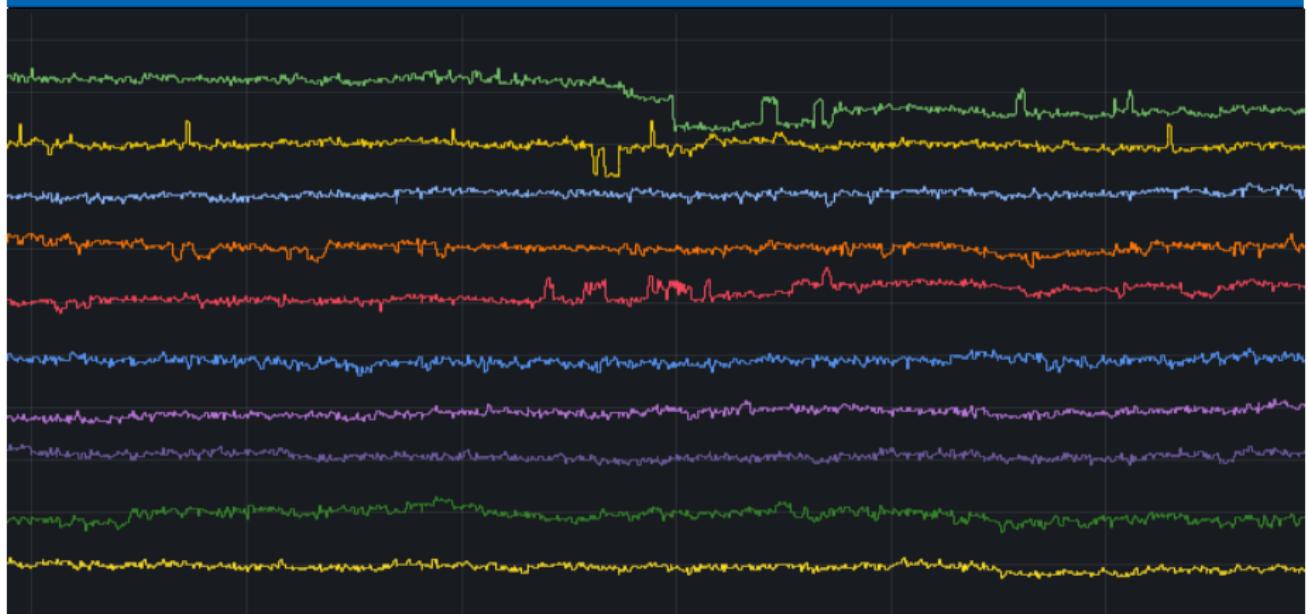


The Quest for Quiet - Tales from the Lab



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The Project

Building a Quantum Computer



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Goal: Quantum computer with single atoms

- Needs lasers (dozens!)...
- and current sources...
- and voltage references...

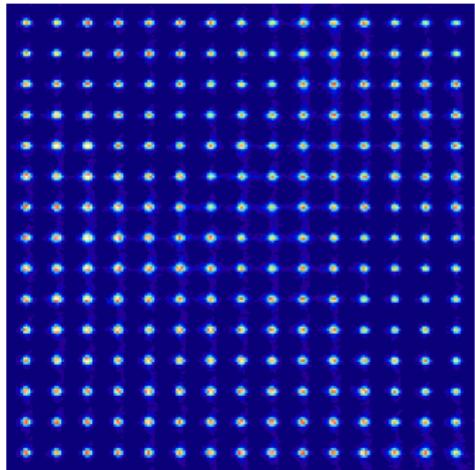


Figure: Array of 15x15 trapped neutral atoms

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Diode Laser System

Requirements



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Requirements:

- Low noise
- Low drift with temperature ($<1 \text{ ppm K}^{-1}$)
- Output current: up to 500 mA
- Compliance voltage: up to 10 V



Current Driver

The state of the art



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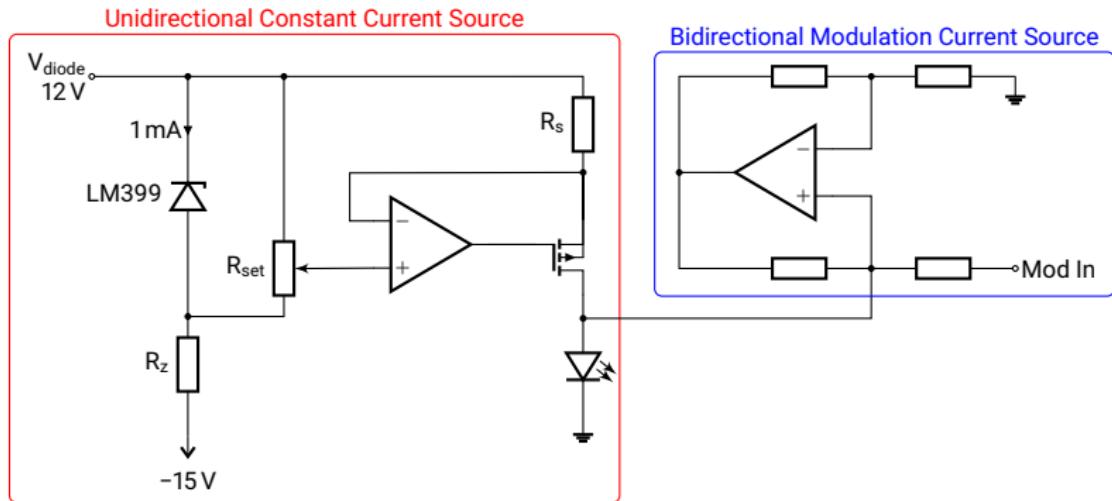


Figure: Simplified current source based on [1]



Current Driver

The state of the art



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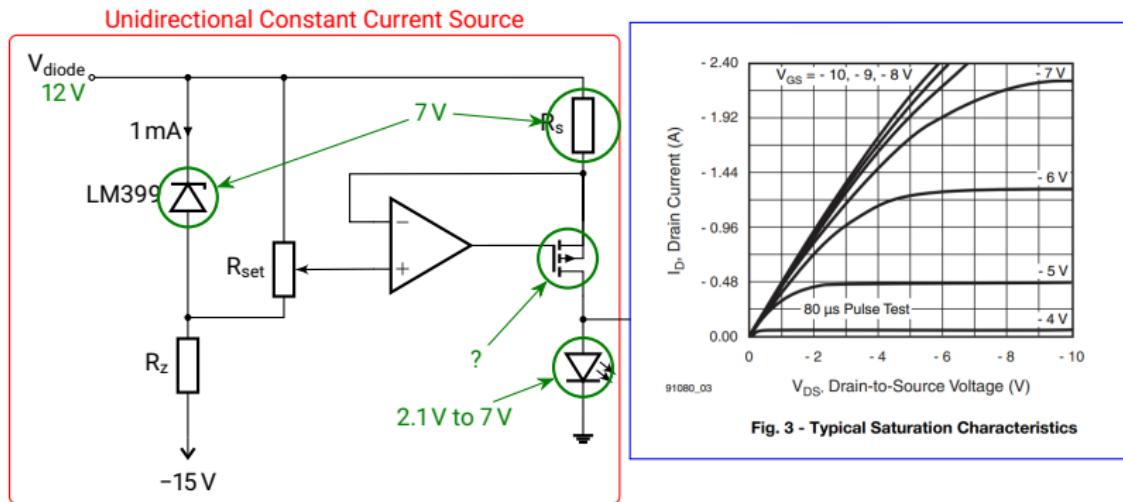


Figure: Simplified current source based on [1], inset: [2]



Current Driver

Our solution

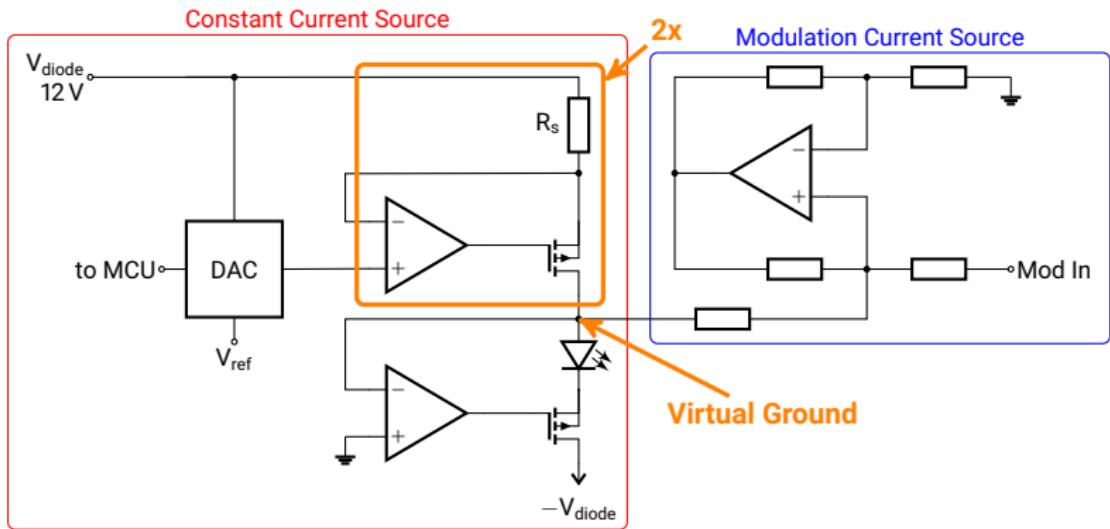


Figure: Simplified current source, APQ design

Current Driver

Noise Source



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Sources of Noise:

- Wideband
 - Reference noise can be filtered
 - Op-amp must be low noise (AD797)
- Low frequency noise
 - Dominated by reference noise
 - LM399 vs. ADR1399 vs. LTZ1000
 - Popcorn noise!
 - References need to be tested.
Each and every one!?

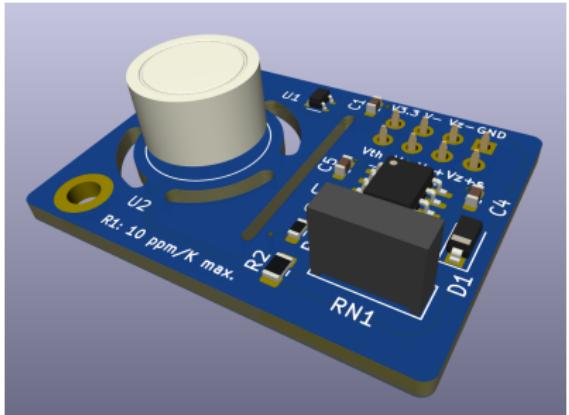


Figure: LM399 -15 V reference, Available at [3]



Testing Voltage References



Figure: Test setup for voltage references. Images taken from: [4]

- 10 measurants every 18 s (2×10^5 relay operations @ 1000 h)
- Keithley 2000-SCAN is rated at 1×10^5 to 1×10^8 operations



Testing

Corona and Home Office



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Figure: Reverse engineering the 2000-SCAN protocol



Testing

Open Source Scanner Card

- 10- or 20-channel scanner card
- All solid state relays
- Silent
- iCE40 FPGA-based to meet timing requirements of the K2002 item Fully compatible with DMM6500 and Model 200x
- Open source toolchain

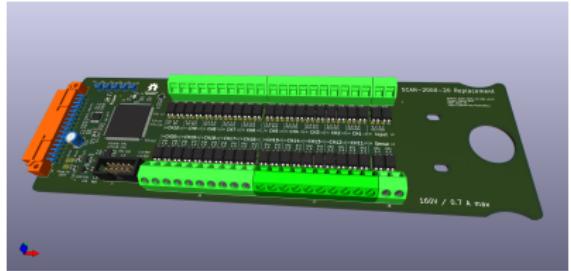


Figure: Available at [5]

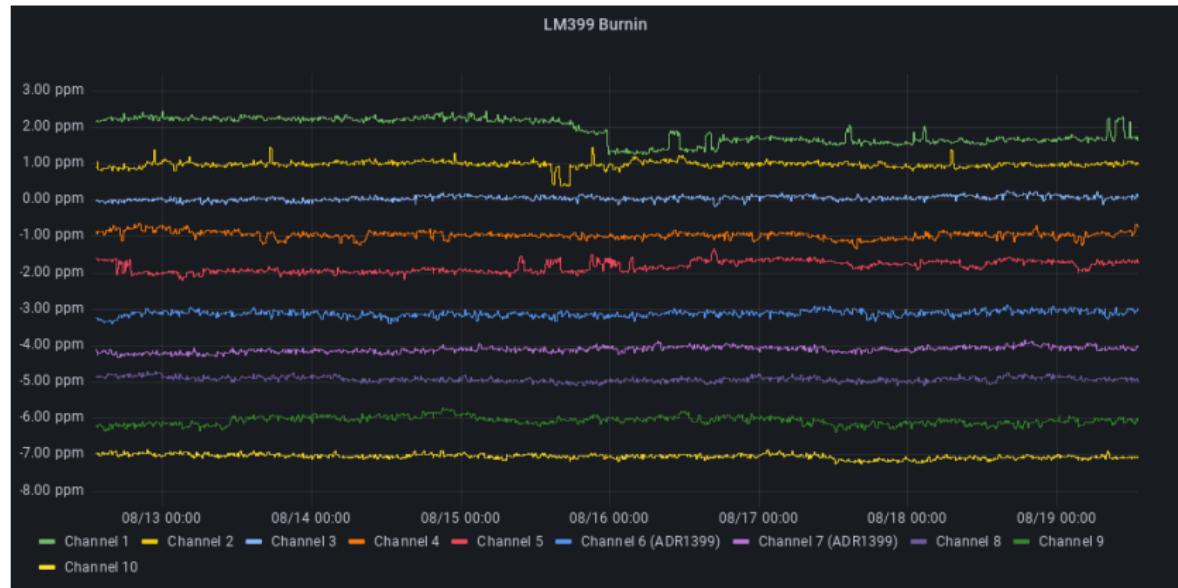


Test results

LM399 vs. ARD1399



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Test results

In numbers



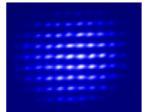
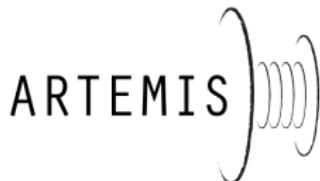
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Our experience with the LM399/ARD1399:

- All diodes are tested over 1000 h
- Tested over 100 LM399 samples
- Tested around 10 ADR1399 (100 more on order)
- LM399 popcorn noise is about **0.4 ppm to 0.6 ppm**
- Around **40 % to 50 %** of the LM399s show excess popcorn noise and get tossed
- ADR1399 shows (nearly) no popcorn noise

Is the ADR1399 the future? - Time will tell. See you in a few months.





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Fachbereich Physik



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Thank you very much for your attention!



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Bibliography I



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-
- [1] K. G. Libbrecht and J. L. Hall.
A low-noise high-speed diode laser current controller.
Review of Scientific Instruments, 64(8):2133–2135, 1993.
 - [2] Vishay Siliconix.
IRF9610 Datasheet, 2021.
Rev. C.
 - [3] Patrick Baus.
LM399 Sub-ppm Voltage Reference.
https://github.com/TU-Darmstadt-APQ/Voltage_reference,
2019.



Bibliography II



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- [4] Keithley 2002 8.5 Digit Multimeter with Scanning.

<https://www.tek.com/en/products/keithley/digital-multimeter/2002-series>.

Accessed: 2012-08-26.

- [5] Patrick Baus.

Keithley SCAN2000 SSR Replacement.

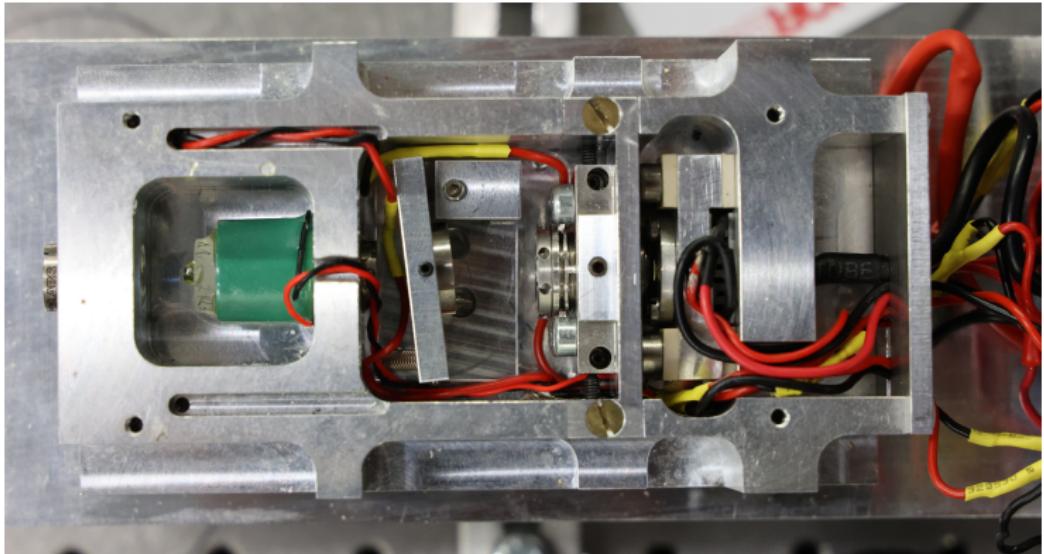
<https://github.com/PatrickBaus/SCAN2000>, 2022.



Laser Resonator



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Current Driver

Comparison with commercial alternatives



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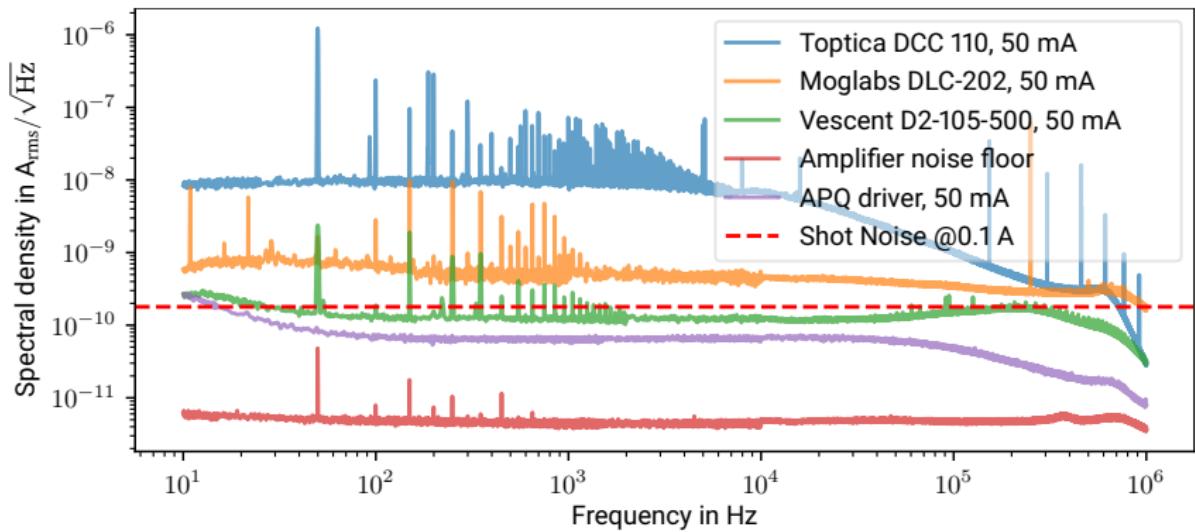


Figure: Current noise spectral density of different commercial drivers