An approximation of the impact of laser driver noise on QCL line-broadening

INTRODUCTION

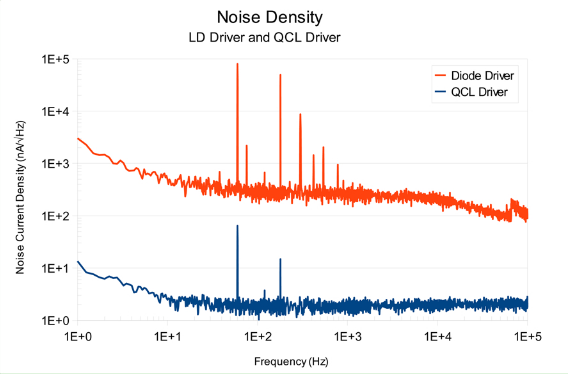
The high power output and ultra-narrow lasing linewidth of quantum cascade lasers (QCLs) enables unprecedented measurement capability in spectroscopy applications. Well designed QCL-based systems can detect and measure trace gases in the parts-per-trillion range, but in order to achieve such performance the entire system must be designed with the utmost attention paid to electronics noise.

We present measured noise spectra of two laser drivers: one is a benchtop laser diode driver, and the other is an ultra-low noise driver designed especially for quantum cascade lasers. Also presented is the noise spectrum addition from a function generator used to modulate the laser driver. Finally, we illustrate an approximation of the effects of total driver noise on QC laser linewidth.

BASELINE DRIVER NOISE

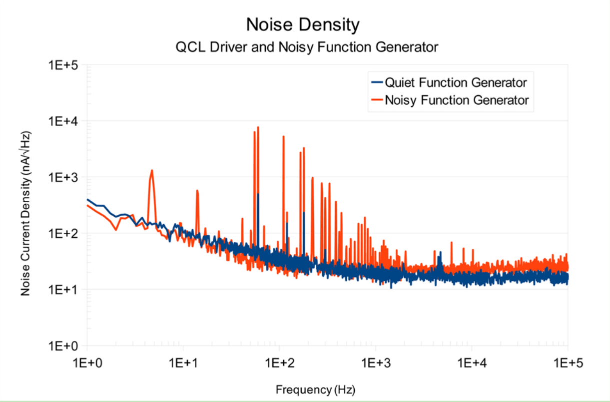
To date, quantum cascade laser applications have been limited by driver electronics noise. Recent advances in driver circuit design have yielded noise reductions of two or three orders of magnitude over previous driver models, finally allowing researchers to achieve the high precision applications QCLs can support.

Foremost in the noise equation is the QC laser driver. Available benchtop laser diode drivers typically have a high enough current noise density to prevent system designers from taking full advantage of the QCL's unique capabilities. This figure shows the noise spectra of a typical benchtop laser diode driver compared to a new ultra-low noise QCL driver.

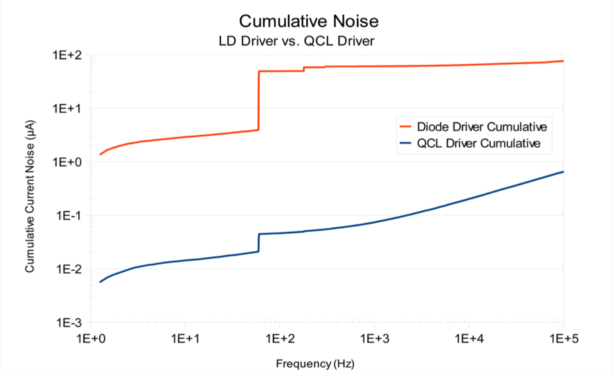


FUNCTION GENERATOR AS A NOISE SOURCE

Wavelength scanning is easily accomplished with QCLs because the wavelength varies with drive current. In the lab a benchtop programmable function generator is often used to modulate quasi-CW laser drivers, but the noise from such a device may be entirely unacceptable for QCL applications. Using a typical benchtop function generator to modulate the QCL driver results in dramatically increased output current noise, which translates to laser line broadening.

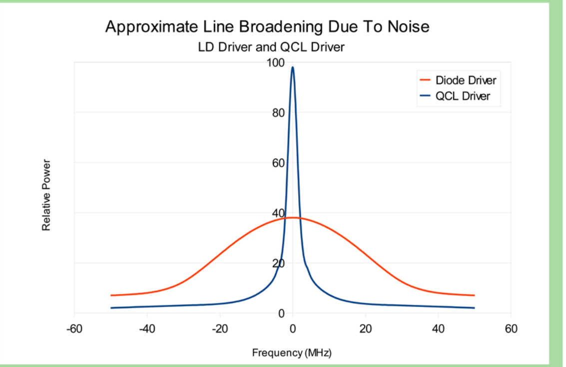


Modulating the current with a low-noise function generator dramatically reduces noise density and cumulative noise, and suggests that additional effort with the function generator will yield further improvements.



THE EFFECTS OF DRIVER NOISE

Integrating over even short time periods, noise on the driver electronics adds up to a broadening of the laser line. This graphic is an approximation based on test results reported by Wavelength's industry partners, but is not a presentation of actual data.



Driving the QCL with a low-noise laser diode driver and integrating over a suitable time period results in a laser linewidth of approximately 40 MHz. Switching to the ultra-low noise QCL driver, and making other improvements in the electronics, narrows the spread to 300 kHz.

Quantum cascade lasers produce sub-kilohertz linewidths, and it is clear that electronics noise has a direct and dramatic impact on the overall line-broadening. Realizing the ultimate linewidth of the QCL requires utmost care in selecting and applying the driver electronics.

REFERENCES & ADDITIONAL RESEARCH

T.L. Meyers, C. Gmachl, et. al., *Free-running frequency stability of mid-infrared quantum cascade lasers*, PNNL and Bell Laboratories, 2001

J. Wojciechowski, *Troubleshooting Low Noise Systems*, Wavelength Electronics, 2011

S. Bartalini, et.al., *Observing the intrinsic linewidth of a quantum-cascade laser: beyond the Shawlow-Townes limit.* 2010

J. Wojciechowski, various internal research and design efforts, Wavelength Electronics, 2011

Wavelength Electronics is actively seeking research partners to quantify the effects of driver noise on the performance of QCL-based detection and measurement systems. Please contact Bob Spetz at bspetz@teamwavelength.com for information on participating in a joint research program.

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