PPCL700 noise testing

Application note Amplitude and Frequency noise

This application note describes the typical noise spectrum of the Pure Photonics PPCL700 laser. Note that efforts are ongoing to improve (or just change) the spectrum further.

The correlation between noise spectrum and application performance can be tricky as the application is sometimes specifically sensitive to some frequencies and in some (or most) cases the relationships are not well understood.

Contents

1. Measurement method

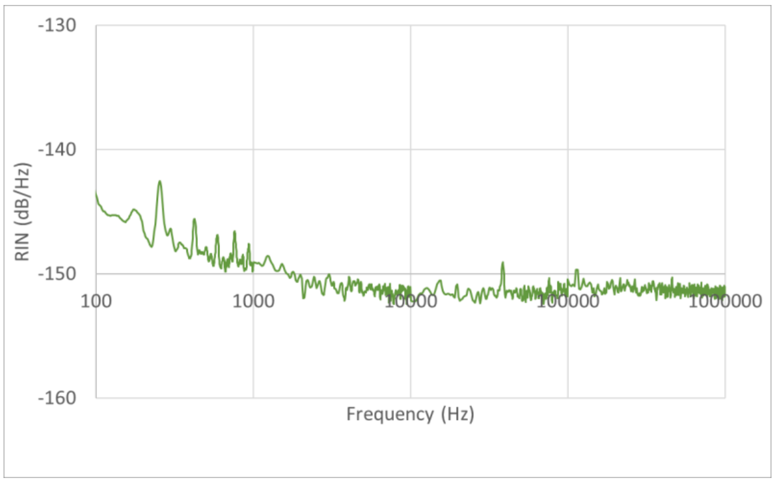
The PPCL700 is operated either on a PPEB700 evaluation board or within a PPCL550 enclosure (we find that the power supply configuration has limited effect on the noise, within those systems). The laser is set to a specific power and frequency (to the first order, laser frequency does not impact the noise spectrum) and the light is detected by a DC photodiode with amplifier (Thorlabs PDA10CS-EC) the electrical spectrum is detected by a 10Hz-150MHz ESA (HP 3588A).

In case of Frequency noise measurements, the laser is set to the frequency 195.8972 and the light is guided through an Ethylene gas cell. This frequency is outside of the absorption peak of the gas-cell and serves as reference. We then move the frequency down to find the -3dB point. We know the responsivity of the gas-cell (about 5mV per MHz) from scanning the gas cell absorption peak.

In both cases the light intensity on the photodiode is controlled to get a 2V DC output voltage from the photodiode amplifier.

We have characterized the photodiode (and ESA) noise spectrum by setting the ESA to fixed frequency ranges and fixed sensitivity settings and performing scans with 100x averaging. We do this for an open input (i.e. no signal into the ESA) and for the photodiode amplifier connected without input optical signal. This provides an indication of the noise floor. In practice we find that the noise floor of the photodiode is a little bit higher (which we derive from the actual measurements).

The below figure shows the noise floor of the RIN over the frequency range.

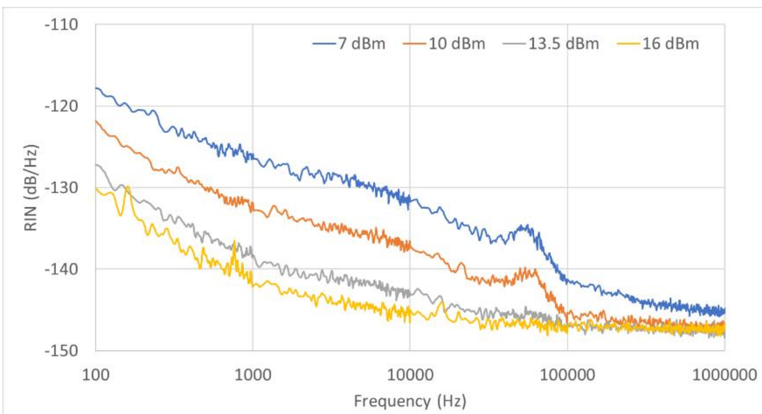


2. RIN measurements

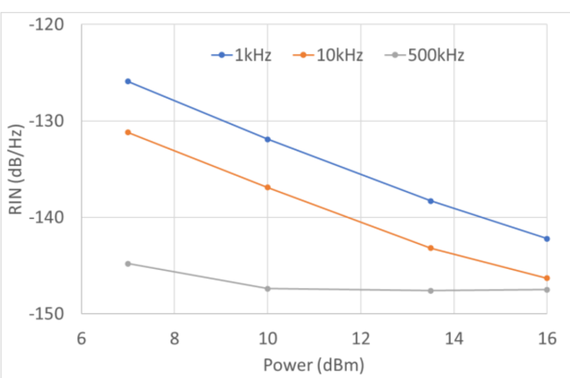
We collected the RIN spectrum of several tunable lasers. In general the performance is very consistent. There are essentially two configurations: with AM circuit and with standard circuit. We first present the data in the whispermode as this is most relevant and cleanest.

RIN versus output power (standard circuit)

For a unit with a standard circuit, the noise behavior is shown below. At higher powers, the RIN value goes down across the spectrum, The RIN filter at around 50kHz is clearly visible at 7dBm, but at higher powers it is not visible anymore as the baseline noise is already close to the photodiode noise floor. The yellow line (16dBm) is already fairly close to the noise floor of the PD across the spectrum, as can be seen because the RIN value does not drop at 2dB per dB power anymore (i.e. approaching the noise floor). Based on the data it appears that the 16dBm data is the real noise limit of the system beyond 10kHz and represents the inherent noise of the photodiode plus additional shot noise from the light interaction.

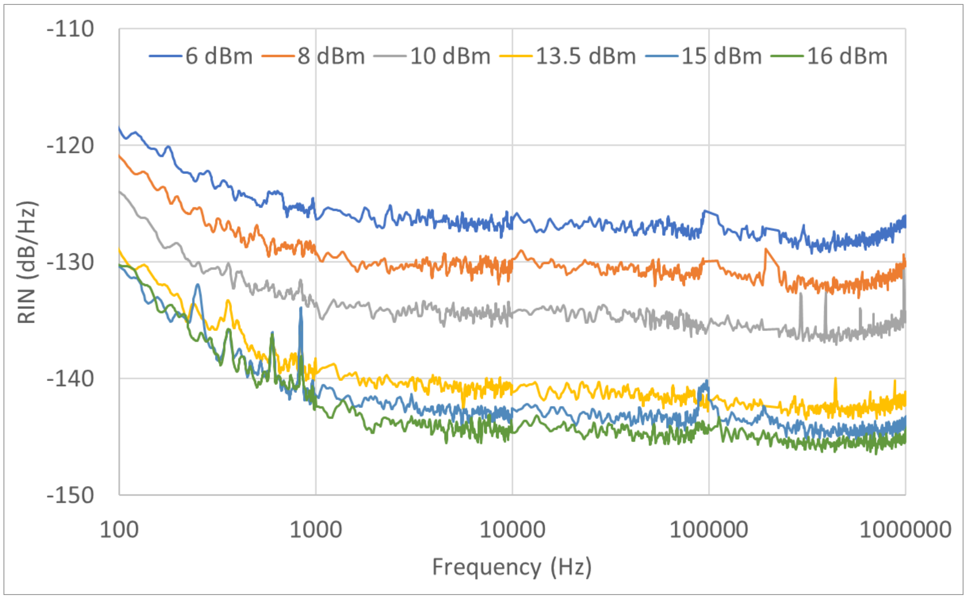


The RIN at 1kHz, 10kHz and 500kHz is shown versus power in the below graph. Across the spectrum the noise seems to drop by 2dB / dB power. At 16dBm, 500kHz, the RIN is expected to be well below -150dB/Hz.

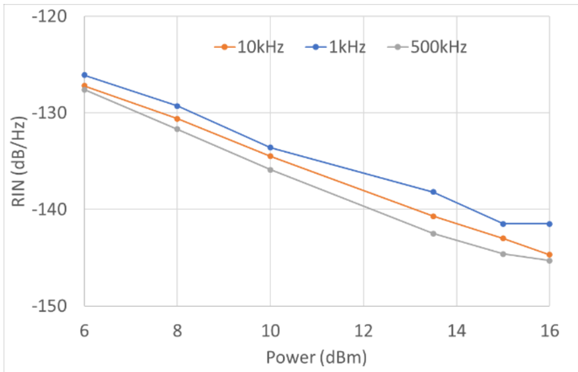


RIN versus output power (AM circuit)

The AM circuit allows modulation on pin 16 to reach the laser through the gain current circuit. As such the RIN can not be filtered like on the standard circuit. The below graph shows the RIN versus power (note that tones at 100kHz and 215kHz at lower power were removed as the calculation to translate ESA readings to RIN is not applicable to peaks).

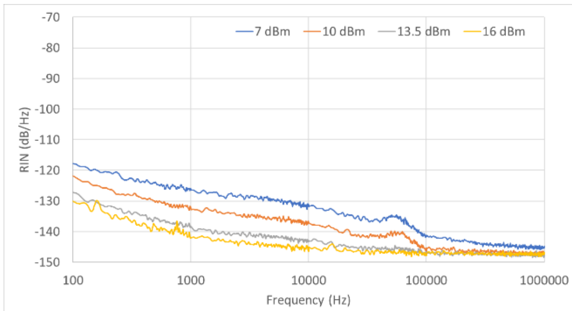


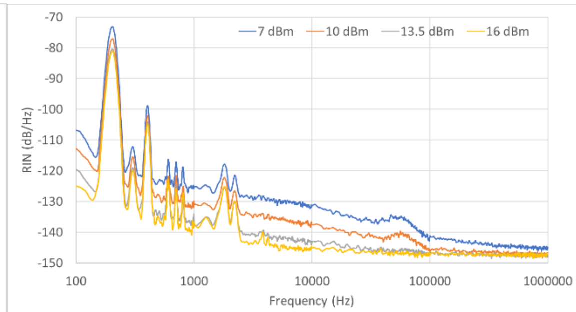
The RIN at 1kHz, 10kHz and 500kHz is shows below. At lower frequencies the differencs with the standard circuit is minimal, but at 500kHz there is a strong difference, as this design allows modulation signals up to 1MHz to reach the laser.



RIN in dither and whisper mode (standard circuit)

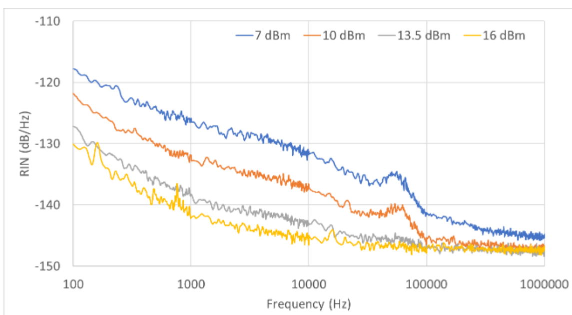
The RIN is compared between the dither mode and the whispermode. The dither (mostly FM) can still be clearly seen in the AM noise. Additional resonances, related to the dither frequency at 200Hz, are also visible. The whispermode noise is 50dB lower at the dither frequencies and overall, the base level is a couple of dB lower. At higher frequencies, beyond 10kHz, no impact is seen (as can be expected).

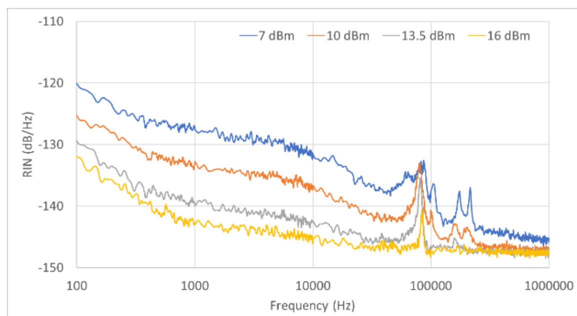




RIN for standard circuit with or without Frequency Modulation

The spectrum for a unit with (right) or without (left) FM modulation option looks fairly similar at lower frequencies. However, around the resonance frequency of the PZT (150kHz) some additional features are visible. The overall noise remains low though. This is attributed to the changes in the drive circuit of the dither and to the noise path from the high voltage amplifier to the PZT to have a higher band-pass frequency. Additional work is ongoing to improve this behavior.





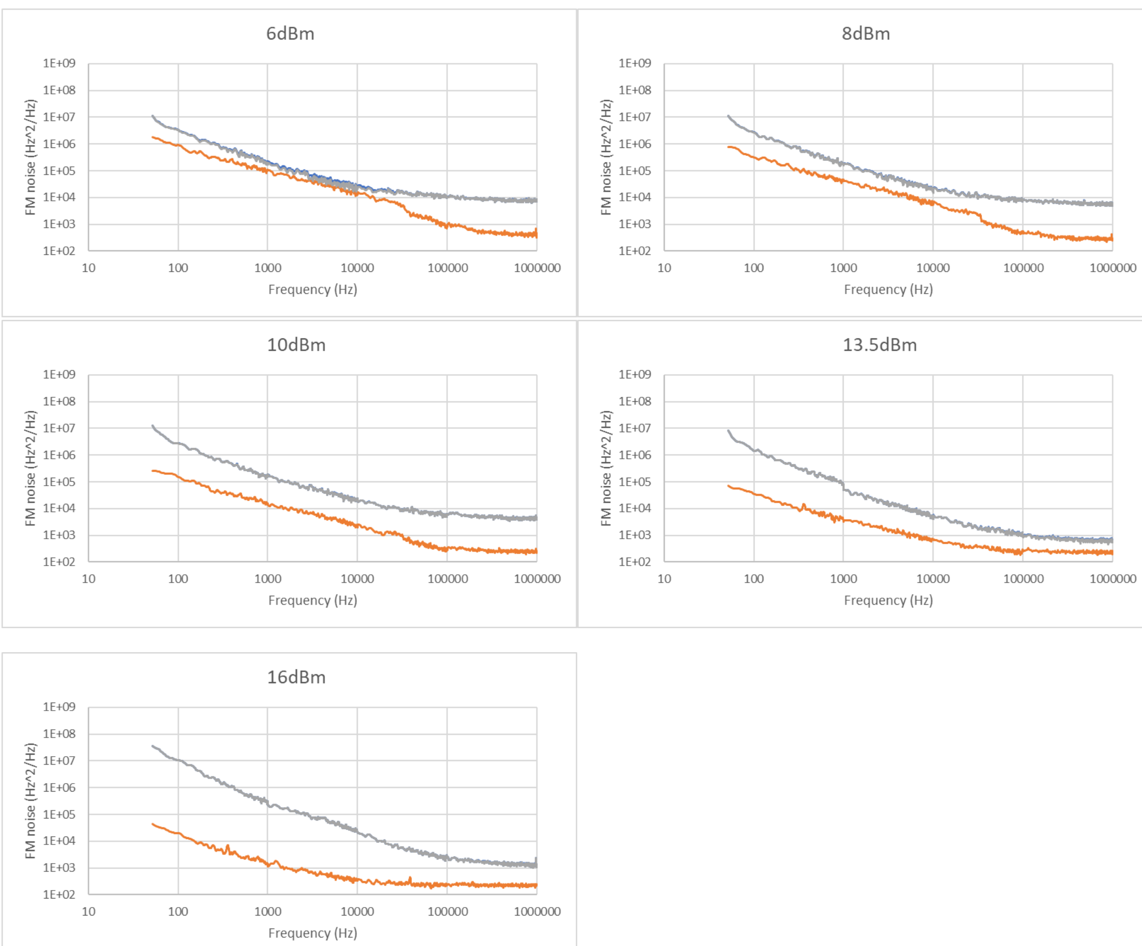
3. Frequency noise measurements

The frequency noise measurements through the gas-cell contain a combination of frequency and amplitude/RIN noise. Hence these measurements always need to be compared back to the matching RIN measurement. Only noise values well in excess of the RIN values would give reliable data on the frequency noise.

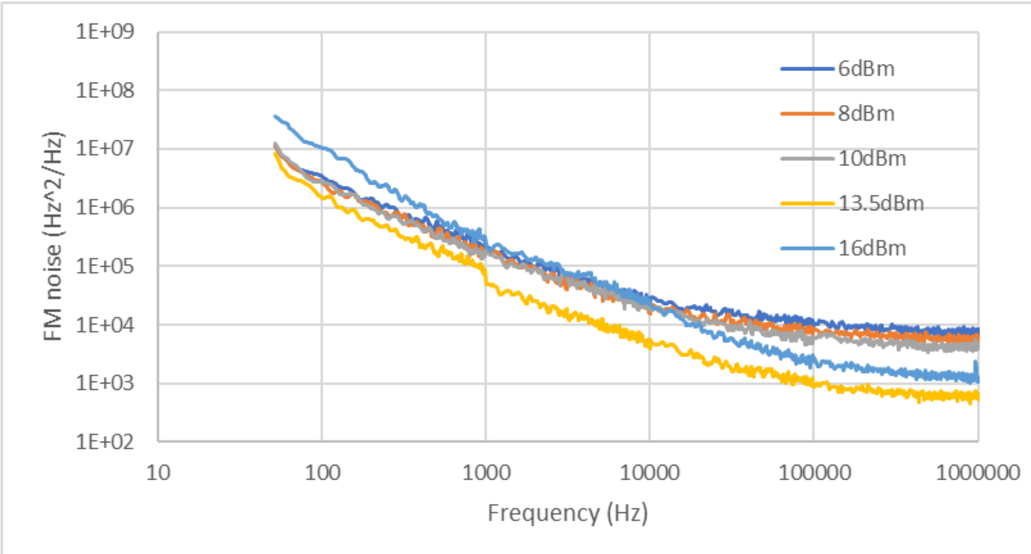
The measurements are normalized to power/Hz. This can then be converted to an amplitude (V/srqt(Hz)). With the response curve of the gascell we can then calculate the noise into Hz/sqrt(Hz) units. And this is converted in Hz^2/Hz units, the most common metric.

Standard configuration

In the below graph the thus calculated frequency noise for a unit is shown versus frequency (grey) at different power levels (the contributions to the spectrum from the AM noise is still included). Also in the graph is the equivalent noise as calculated from the RIN spectrum (orange). And finally, we show an FM noise curve corrected for the AM noise power (blue).

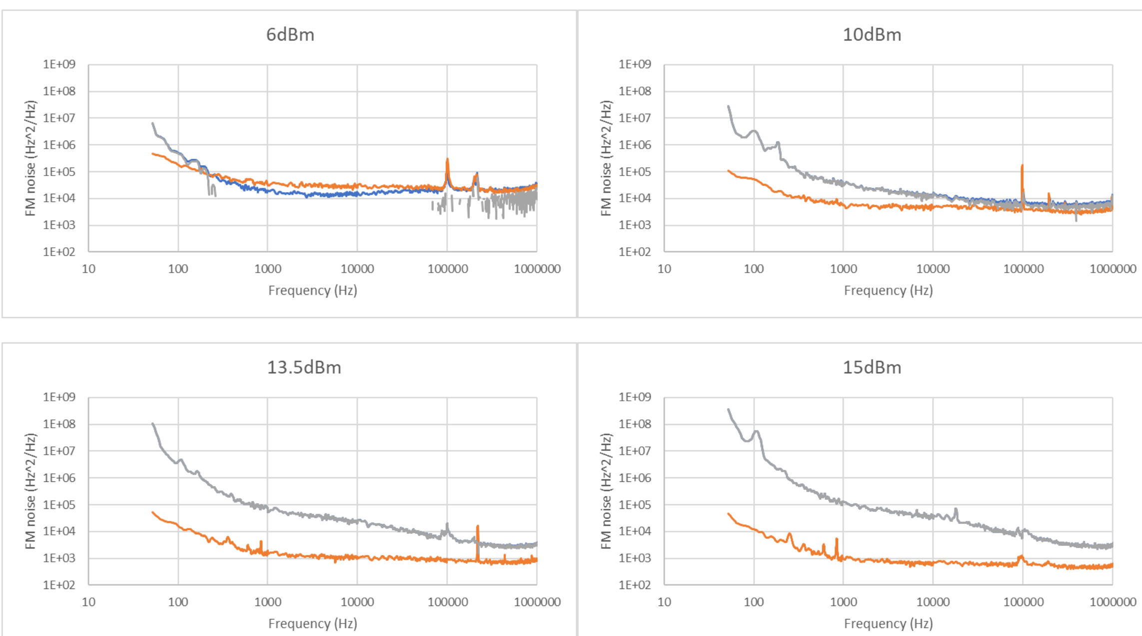


Combining the corrected curves for all power levels in one graph shows that the frequency noise has limited dependence on output power. For the lower powers, the contribution of the AM noise is very close to the FM curve and that data is less accurate.

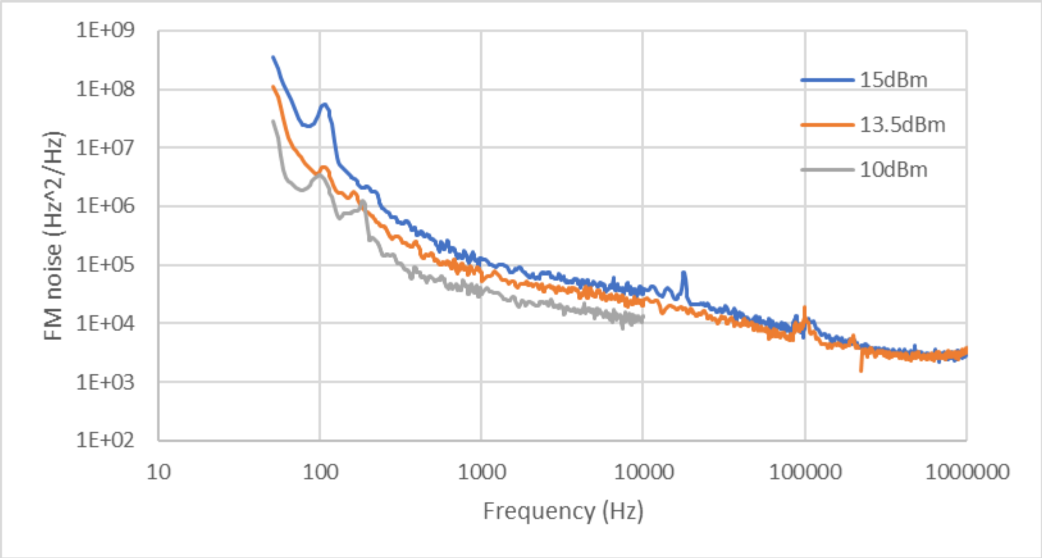


AM configuration

For a device without the low RIN circuit, used for devices with AM modulation up to to 1MHz. The power dependence is shown below.



At the lower power, the AM noise dominates and the FM noise can't be measured accurately. Ignoring that part of the data the noise can be plot for this unit.



The main observation is that the noise level is not dependent on the output power level and that the FM noise with the AM circuit is very similar to the version without the AM circuit (though the AM noise is very different).