LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory / LIGO Scientific Collaboration

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Performance Comparison of New VCO Designs

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LIGO Scientific Collaboration

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1 Introduction

The Low Noise VCO (voltage controlled oscillator) introduces whistles into the LIGO detector data which show up at the gravitational readout channel as glitches. The problem stems from high order intermodulation products generated and down-converted by the mixer in the FDD (frequency difference divider. An updated design is using straight frequency division. We are evaluating 2 VCO chips that operate at 10 or 20 times the nominal frequency.

The wiki link is here and the dcc link is E1200120.

2 Data

The table below lists the tested devices:

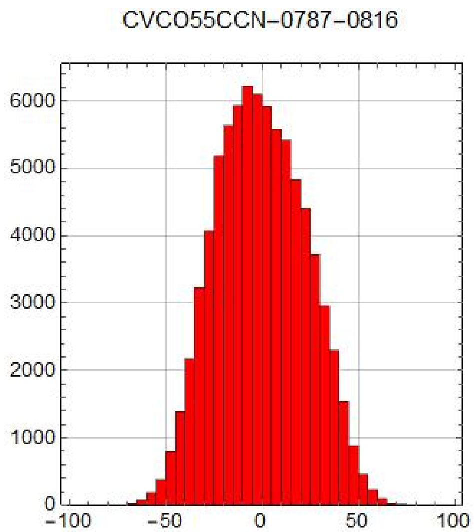
Device	Company	f_L (MHz)	f_H (MHz)	Division
MFC91119-10	Synergy Microwave	910	1190	f/128+71MHz
DCRO159161-12	Synergy Microwave	1575	1610	f/20
CVCO55CCN-0787-0816	Crystek Microwave	787	816	f/10

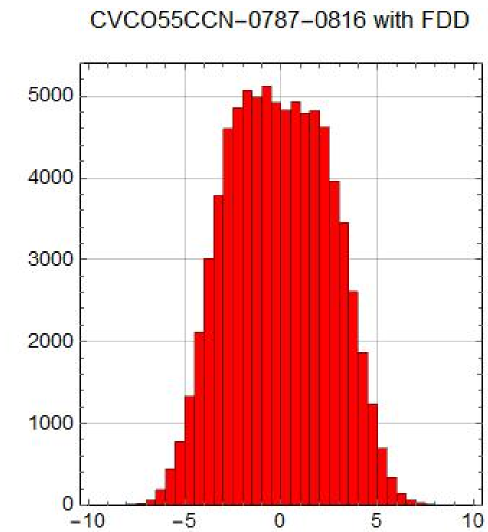
An additional FDD can be added to each of these VCO that uses a frequency difference divider with equation f/10 + 71MHz.

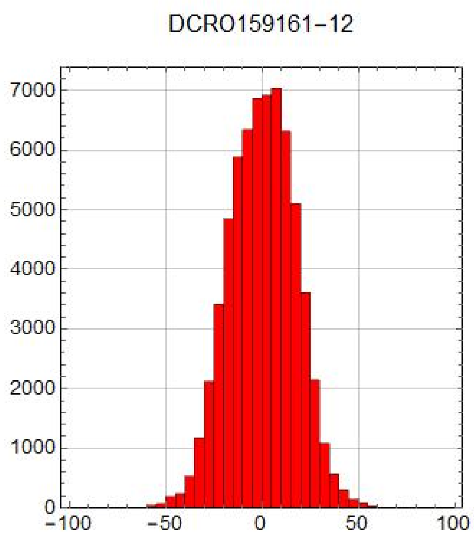
The table below list the available frequency range with and without an additional FDD:

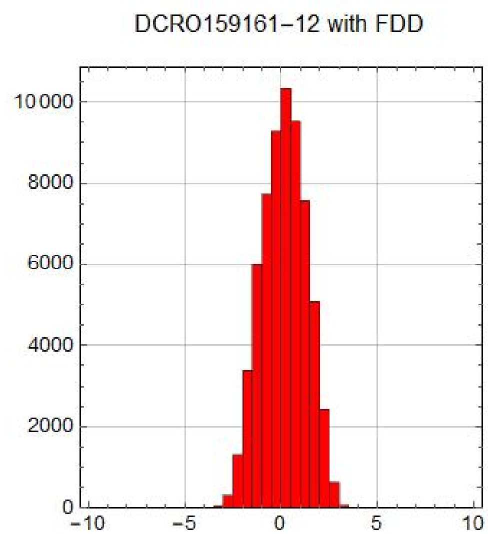
	MFC	DCRO	CVCO
VCO frequency range minimum (MHz)	78.27	78.25	77.5
VCO frequency range maximum (MHz)	80.68	81.25	82.5
VCO frequency range (MHz)	2.41	3.00	5.0
FDD frequency range minimum (MHz)	78.827	78.825	78.75
FDD frequency range maximum (MHz)	79.068	79.125	79.25
FDD frequency range (MHz)	0.241	0.300	0.50
VCO stability (Hz rms)	15.5	17.0	23.2
FDD stability (Hz rms)	2.0	1.2	2.6

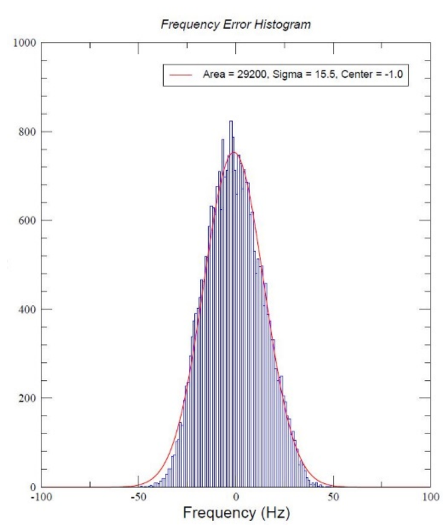
The rms of the frequency stability was measured with the standard Beckhoff/TwinCAT controller. It uses a frequency counter to read out the frequency once a second. A slow servo then keeps the value close to nominal. Histograms are shown on the next page.

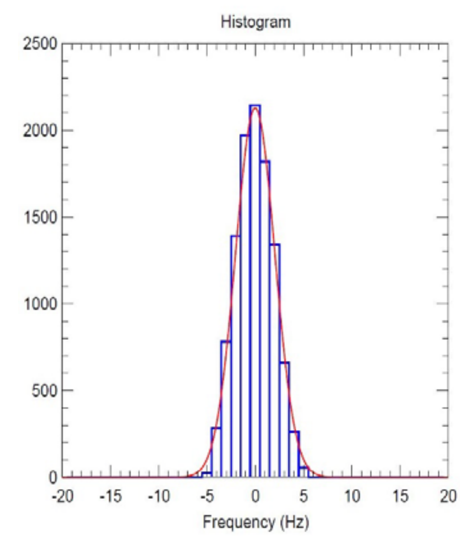

CVCO55CCN−0787−0816


CVCO55CCN−0787−0816 with FDD


DCRO159161−12


DCRO159161−12 with FDD

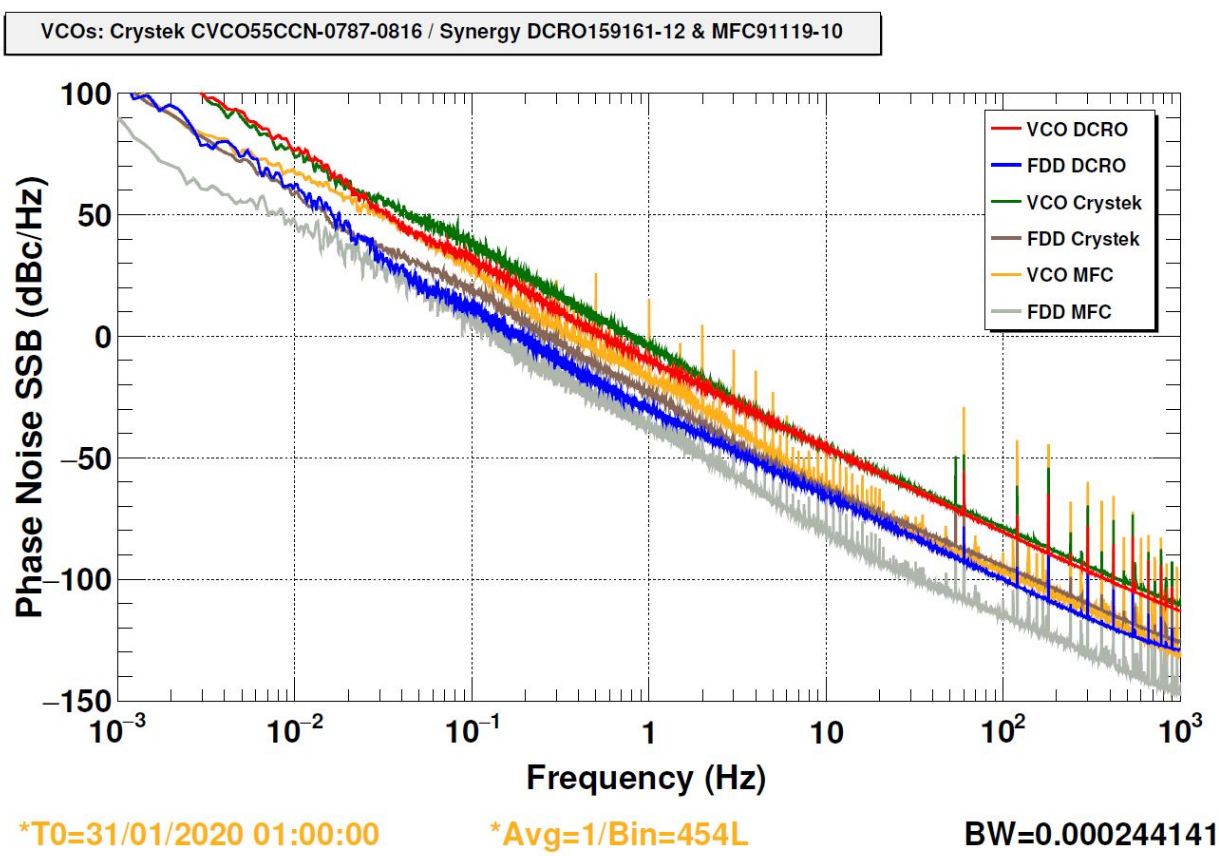

Frequency Error Histogram
Area = 29200, Sigma = 15.5, Center = -1.0
Frequency (Hz)

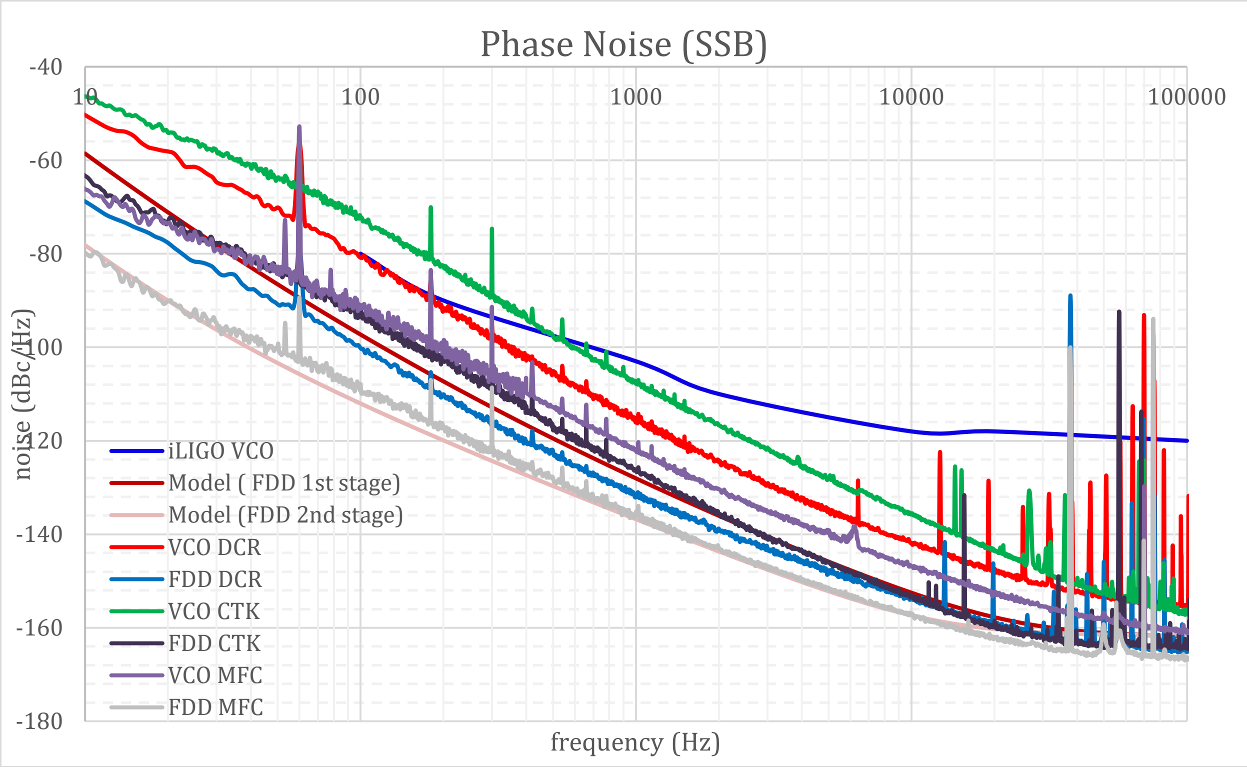

Histogram
Frequency (Hz)

Phase noise was measured two different ways. The Wenzel phase noise testing setup was used to measure phase noise above 10 Hz. For measuring phase noise below 1 kHz we locked the VCO with a PLL and recorded the controls signal.

The table below list the SSB phase noise values at different frequencies.

Phase noise (dBc/Hz SSB)	**MFC**	**DCRO**	**CVCO**
VCO @ 10 Hz	-62	-46	-46
VCO @ 100 Hz	-98	-81	-79
VCO @ 1 kHz	-131	-113	-110
VCO @ 10 kHz	-147	-142	-136
VCO @ 100 kHz	-161	-155	-156
FDD @ 10 Hz	-80	-66	-63
FDD @ 100 Hz	-115	-100	-94
FDD @ 1 kHz	-147	-129	-126
FDD @ 10 kHz	-157	-142	-153
FDD @ 100 kHz	-166	-165	-164





3 Conclusions

As expected the Low Noise VCO has the best phase noise performance. Also as expected adding an additional FDD reduces the range by a factor of 10 and the phase noise nearly by a factor of 10. Between the DCRO and CVCO units the former has about 3dB better phase noise in average, but is worse than the Low Noise VCO by about 18dB.

The DCRO is about as stable as the Low Noise VCO. The CVCO unit is about 50% worse.

The range of the CVCO unit is twice the one of the Low Noise VCO, whereas the DCRO unit is about 25% larger than the Low Noise VCO.

Since the DCRO units has slightly better performance than the CVCO unit, we recommend going forward with the DCRO unit.