



Main Oscillator with sub-fs Resolution and High Performance Local Oscillator Generation in MicroTCA.4

KVG: Jiaoni Bai

DESY: Frank Ludwig, Uroš Mavrič, Heinrich Pryschelski

- 1. KVG Introduction**
- 2. Quartz Crystal Products**
- 3. Main Oscillator with high Power and sub-fs Resolution**
- 4. High Performance Local Oscillator Generation**

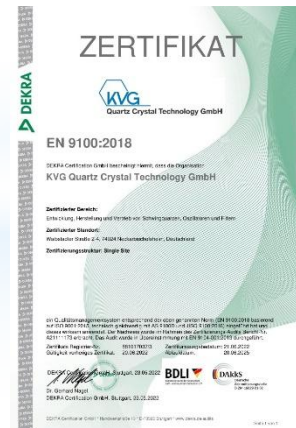
KVG Quartz Crystal Technology GmbH

Location / Headquarter: Neckarbischofsheim,
Germany



We provide

- **state-of-the-art frequency control products for Science & Industry**
e.g., crystals, oscillators, filters, specific quartz crystal products, etc.
- **Customized products, solution and excellent service**
- **Certification**
EN9100 and ISO14001

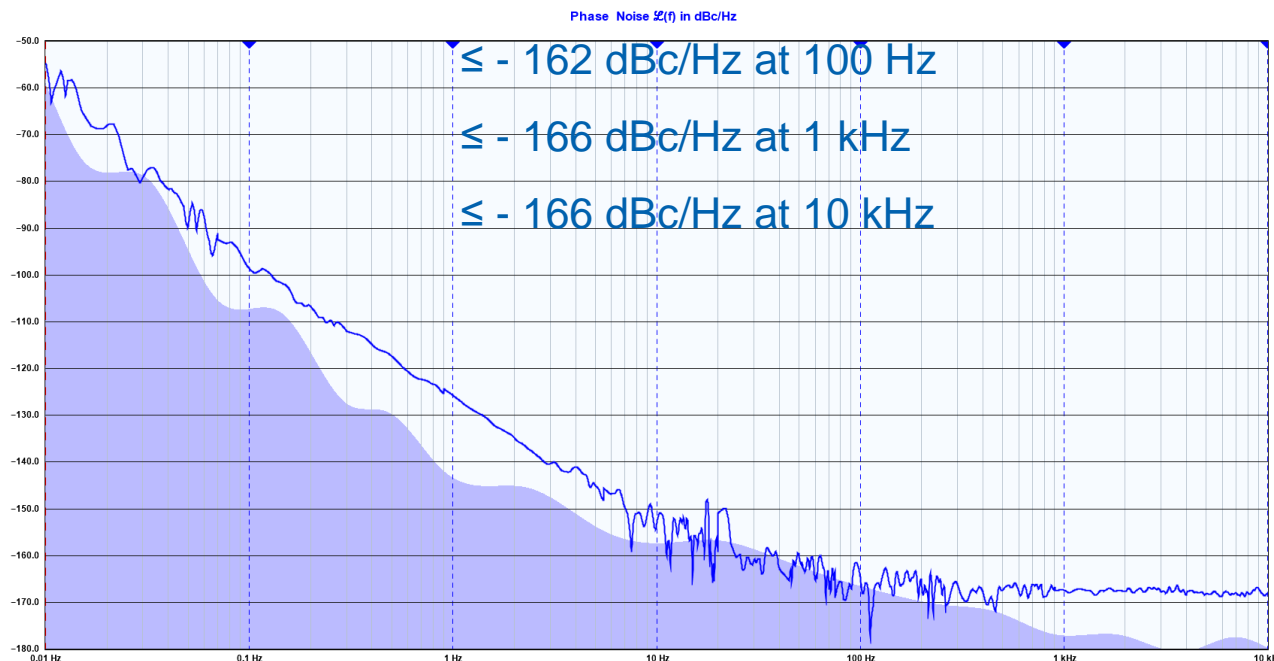


Ultra-low Phase Noise OCXO Series

10 MHz

- **Case:** 51x51x16 mm THT
- **Supply voltage:** 12.0V
- **Current consumption:**
Warm-up ≤ 7.2 W max.
Steady State ≤ 3 W max
- **Frequency stability:**
 $-20^{\circ}\text{C} \sim 70^{\circ}\text{C} \leq \pm 2$ ppb
- **Output power:**
 $\geq +5$ dBm, Sine wave, 50 Ohm
- **Short-term stability:**
 $\leq 9 \times 10^{-14}$ @ $\tau = 1$ sec
- **Aging:**
 $< \pm 20$ ppb per year

- **Phase noise:**
 ≤ -90 dBc/Hz at 0.1 Hz
 ≤ -124 dBc/Hz at 1 Hz
 ≤ -149 dBc/Hz at 10 Hz
 ≤ -162 dBc/Hz at 100 Hz
 ≤ -166 dBc/Hz at 1 kHz
 ≤ -166 dBc/Hz at 10 kHz

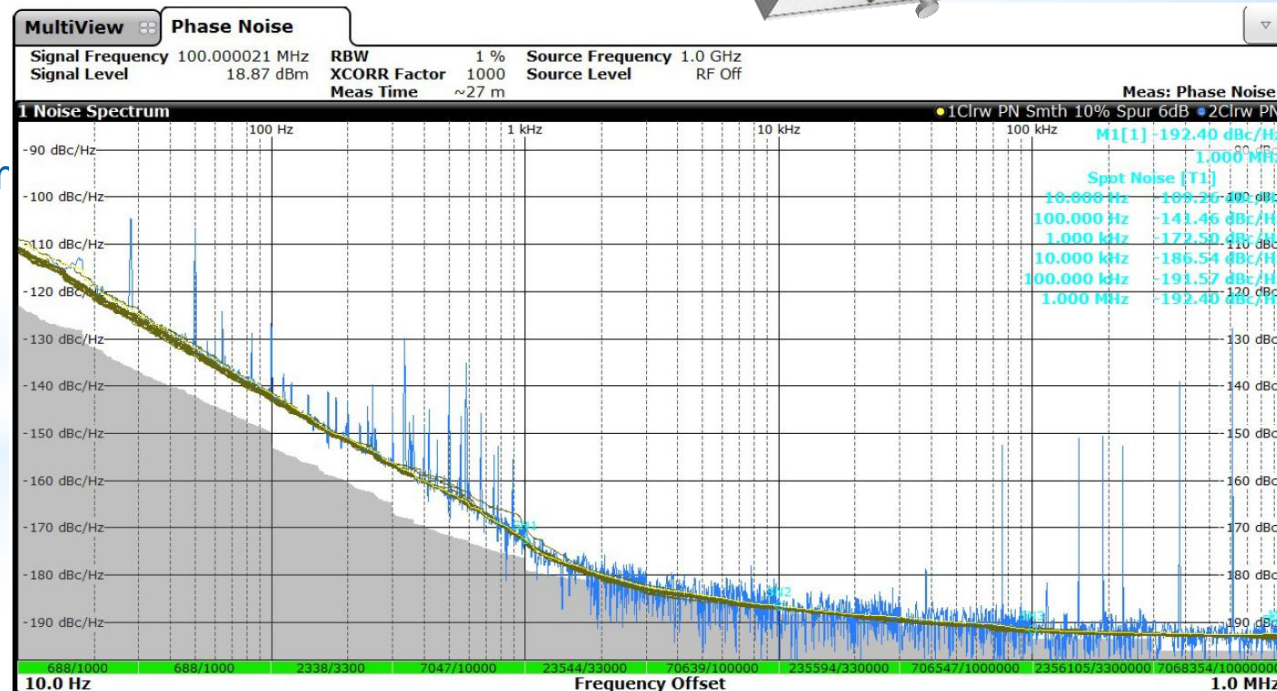


Ultra-low Phase Noise OCXO Series

100 MHz



- **Case:** 51 x 51 x 29 mm SMA
- **Supply voltage:** 12.0V
- **Current consumption:**
Warm-up ≤ 500 mA (6.0 W max.)
Steady State ≤ 250 mA (3.0W max.)
- **Frequency stability:**
 $-20^{\circ}\text{C} \sim 70^{\circ}\text{C} \leq \pm 100$ ppb
- **Output power:**
 $\geq +18$ dBm, Sine wave, 50 Ohm
- **Low aging:**
per year $\leq \pm 300$ ppb
- **Phase noise:**
 ≤ -110 dBc/Hz at 10 Hz
 ≤ -140 dBc/Hz at 100 Hz
 ≤ -170 dBc/Hz at 1 kHz
 ≤ -185 dBc/Hz at 10 kHz
 ≤ -190 dBc/Hz at 100 kHz
 ≤ -190 dBc/Hz at 1 MHz





X14 Ultra-low Phase Noise RF Signal Source

Frequency options:

100 MHz, 300 MHz, 500 MHz,
700 MHz, 1 GHz, 1.3 GHz Up to 24 GHz

External reference input options:

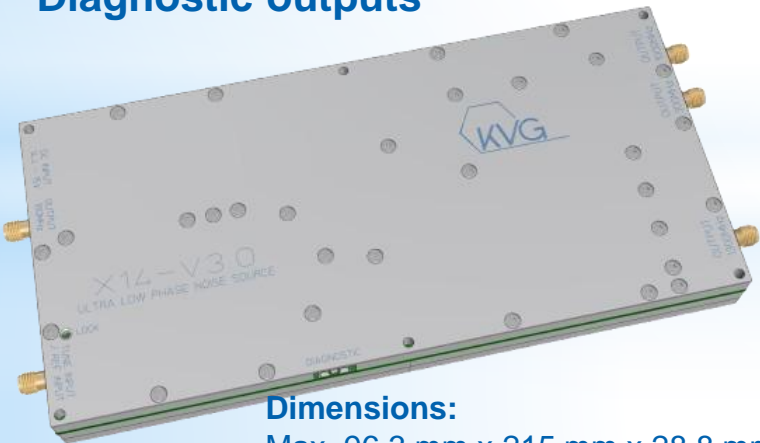
10 MHz, 20 MHz or 100 MHz

External tuning voltage options:

0 5 V or 0 10 V

Supply voltage 14.7V Current 1.5A

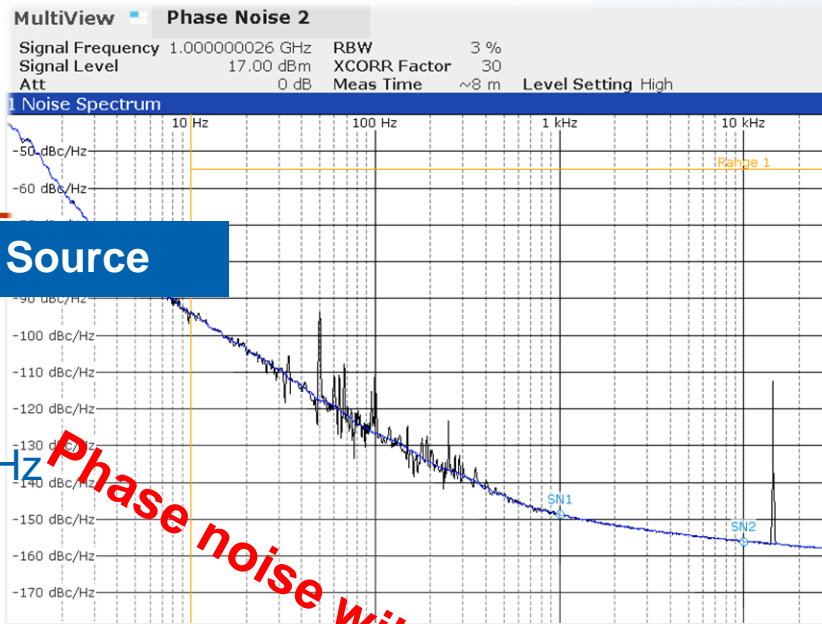
Diagnostic outputs



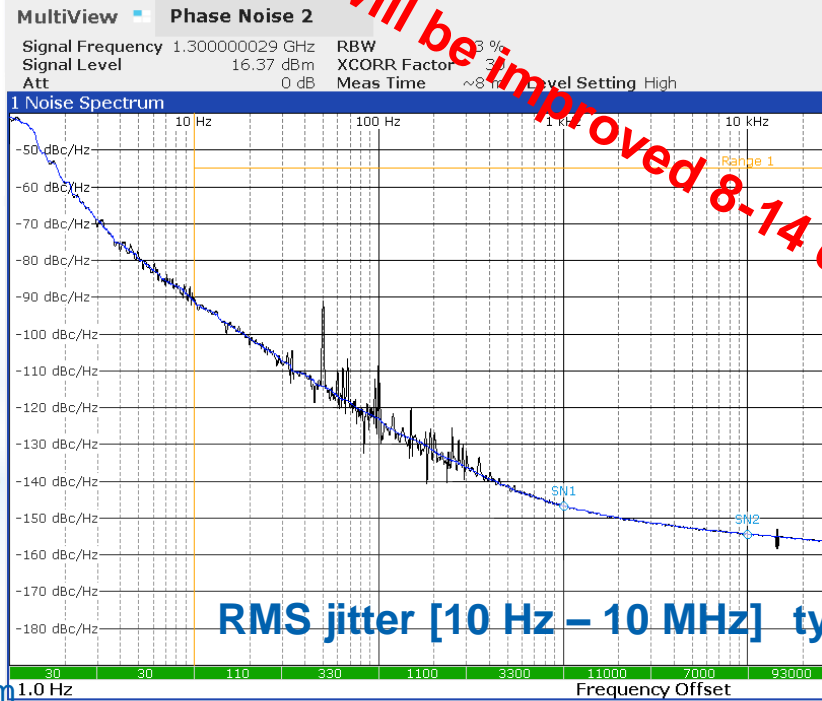
Dimensions:

Max. 96.3 mm x 215 mm x 28.8 mm
incl. connectors

Dr. Jiaoni Bai | 2024 MicroTCA/ATCA



Ultra-low phase noise at 1 GHz
 ≤ -94 dBc/Hz at 10 Hz
 ≤ -126 dBc/Hz at 100 Hz
 ≤ -148 dBc/Hz at 1 kHz
 ≤ -156 dBc/Hz at 10 kHz
 ≤ -160 dBc/Hz at 100 kHz
 ≤ -169 dBc/Hz at 1 MHz
 ≤ -172 dBc/Hz at 10 MHz



Ultra-low phase noise at 1.3 GHz
 ≤ -91 dBc/Hz at 10 Hz
 ≤ -122 dBc/Hz at 100 Hz
 ≤ -146 dBc/Hz at 1 kHz
 ≤ -154 dBc/Hz at 10 kHz
 ≤ -159 dBc/Hz at 100 kHz
 ≤ -167 dBc/Hz at 1 MHz
 ≤ -170 dBc/Hz at 10 MHz

Phase noise will be improved 8-14 dB in 2025/2026.

RMS jitter [10 Hz – 10 MHz] typ. < 10 fs @ 1300 MHz

2 Integrated Measurements

Range	Trace	Start Offset	Stop Offset	Weighting	Int Noise	PM	FM / AM	Jitter
1.0 Hz	1	10.000 Hz	10.000 MHz		-84.57 dBc	4.79 m°/83.59 µrad	75.239 Hz	10.233 fs

Technical Overview

- Custom designed 19" 600 mm 5U housing
- Excellent short-term phase noise and jitter <1fs
- Frequency stability better than 10^{-12} (hours-days)
- Support high power outputs $\geq +46$ dBm
- Provide different frequencies (optional)
- Support remote diagnostic for maintenance
- Tight operational reliability



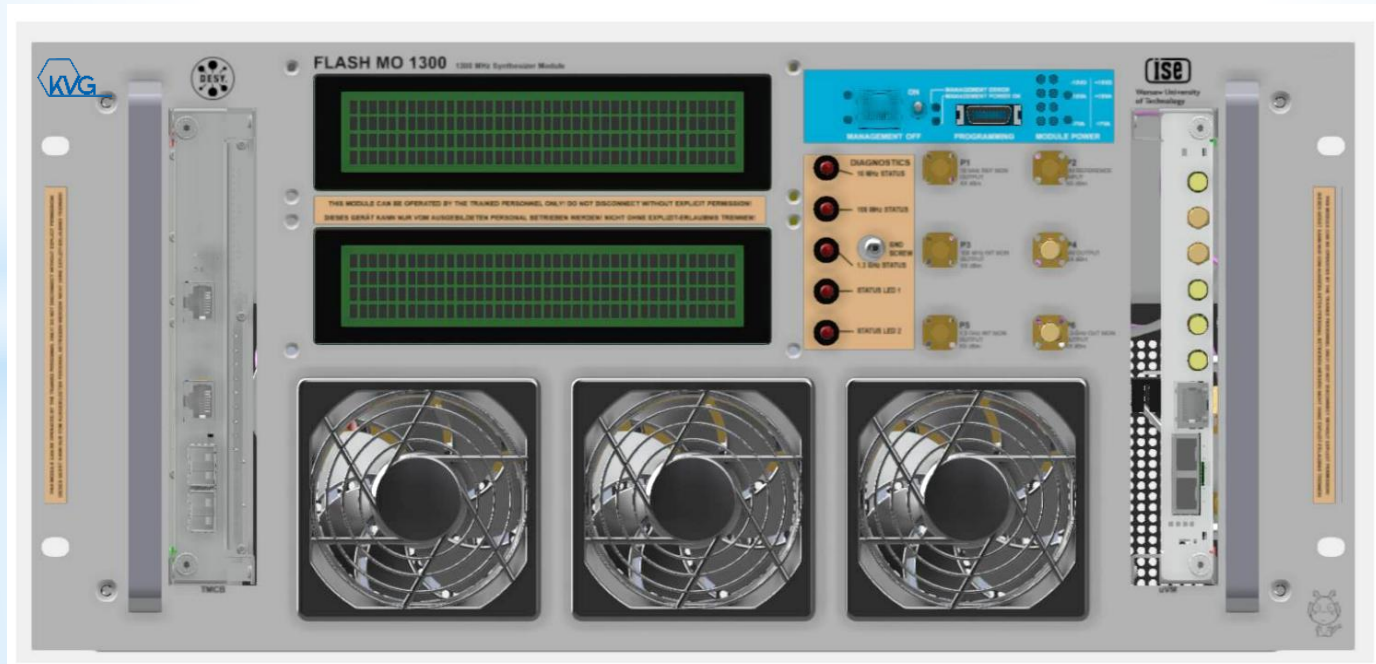
Under license from DESY

- **Typical Application:**
Providing high-power and ultra-low phase noise RF-signals in modern accelerators

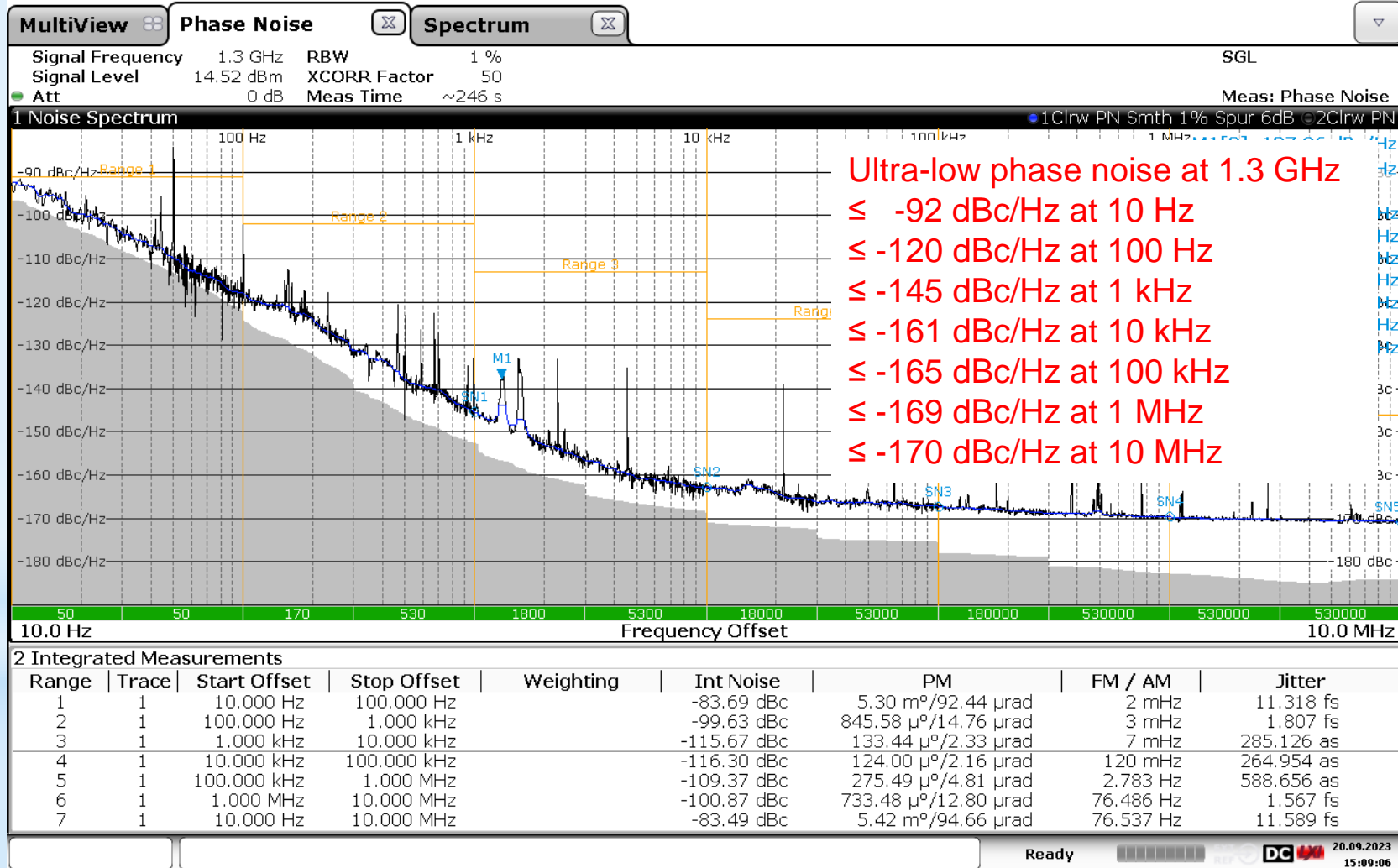


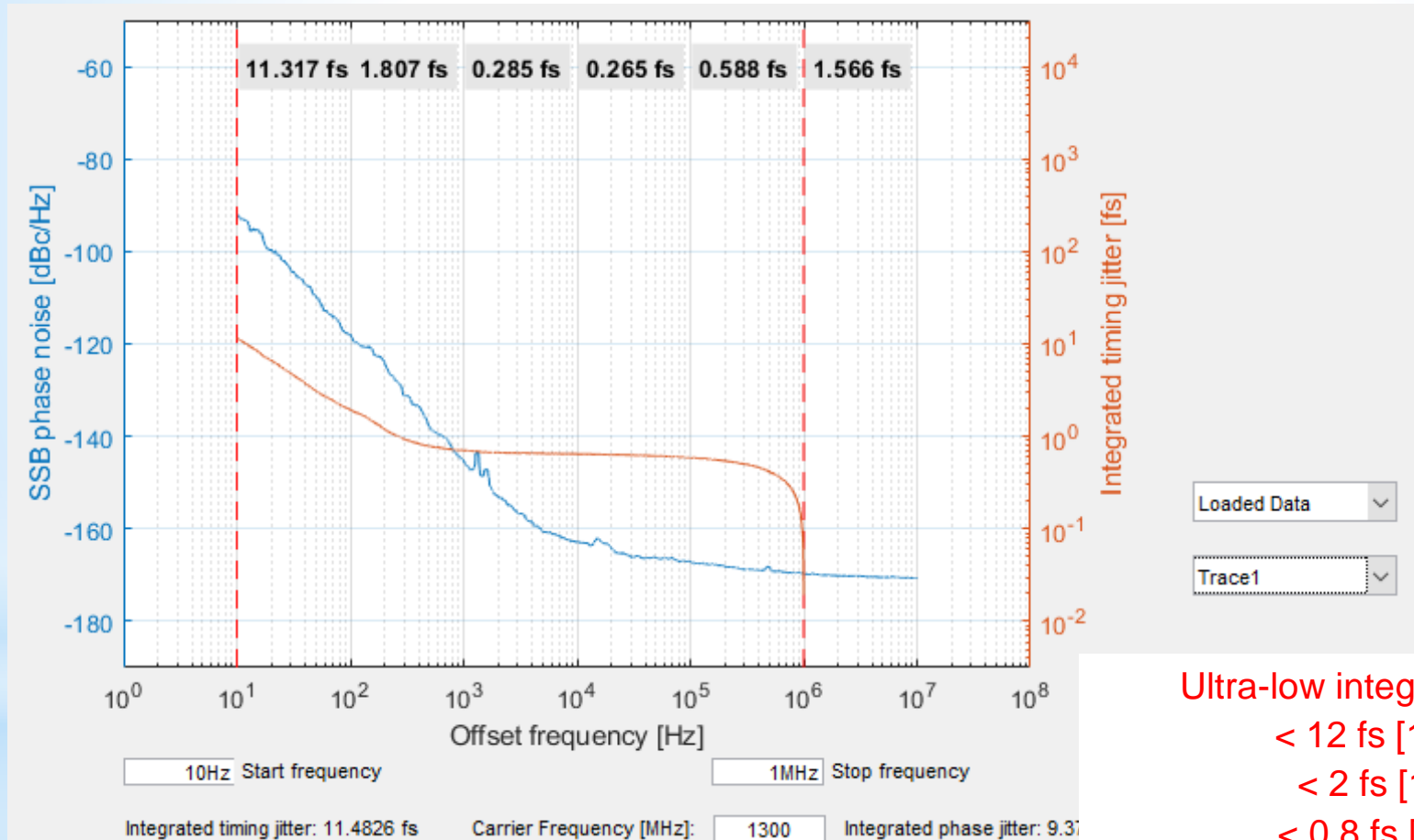
Working Principle

MO synchronizes an ultra-low phase noise DRO output signal with a 1.3 GHz signal synthesized from an ultra-stable GPSDO 10 MHz signal.



RF Performance





Ultra-low integrated jitter at 1.3 GHz
 < 12 fs [10 Hz to 100 Hz]
 < 2 fs [100 Hz to 1 kHz]
 < 0.8 fs [1 kHz to 1 MHz]

Measurement result provided by F.Ludwig and H.Pryschelski (MSK, DESY)

Technical Overview

- A multi-channel local oscillator, RF signal and clock generator
 - 9 REF, 9 LO and 9 CAL signals [400 MHz to 6 GHz]
 - 22 low-jitter, differential CLK signals up to 160 Msp/s
- Two double-width, full-height, MicroTCA.4 compliant extended Rear Transition Module (eRTM)
- LO residual phase noise < 5 fs (rms) [10 Hz to 1 MHz] at 1.354 GHz
- On/Off switching of output clocks and RF signals
- Temperature regulation for long-term stability of RF signals
- Diagnostic for RF power, DC voltage, temperature, humidity



Under license from DESY





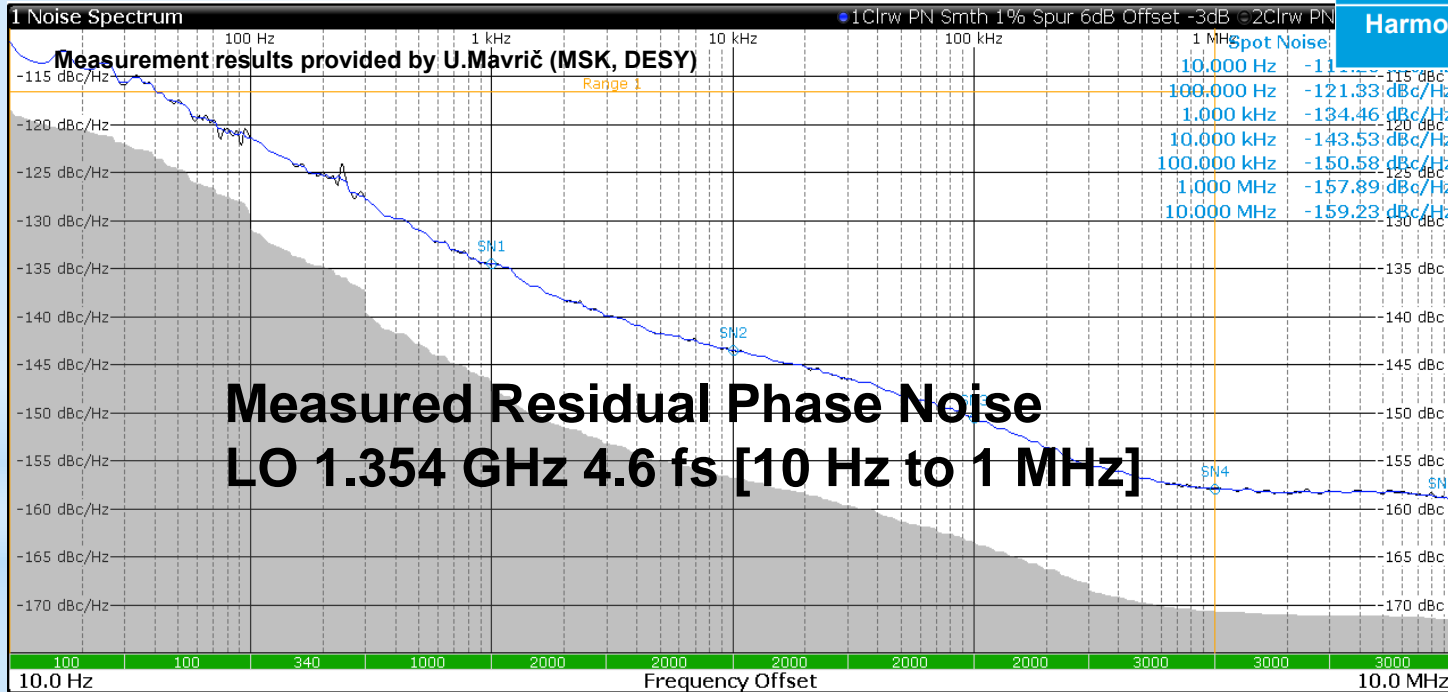
DeRTM-LOG

RF Performance

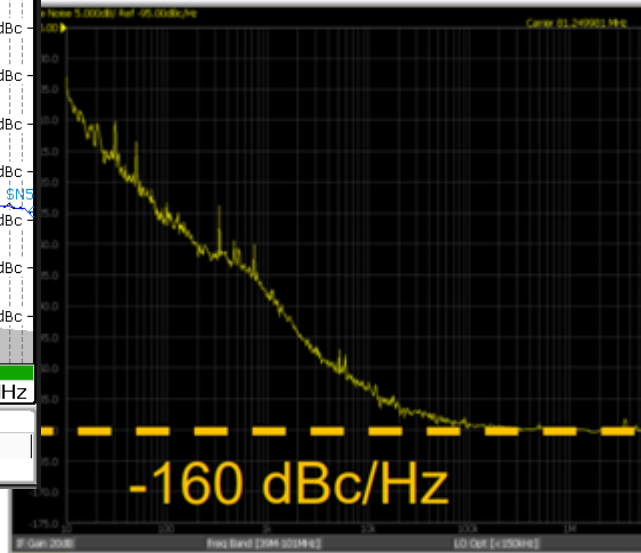
DeRTM-LOG 1.3 GHz:

- REF 1.300 GHz
- LO 1.354 GHz
- CLK 81.25 MHz

RF Parameter	Measured Value (Worst Case)
Return Loss	>20 dB
LO Out Power	>29 dBm
Isolation	>80 dBc
Harmonics (2 nd , 3 rd)	<-80 dBc



Typical CLK (81.25 MHz)
Absolute Phase Noise



2 Integrated Measurements

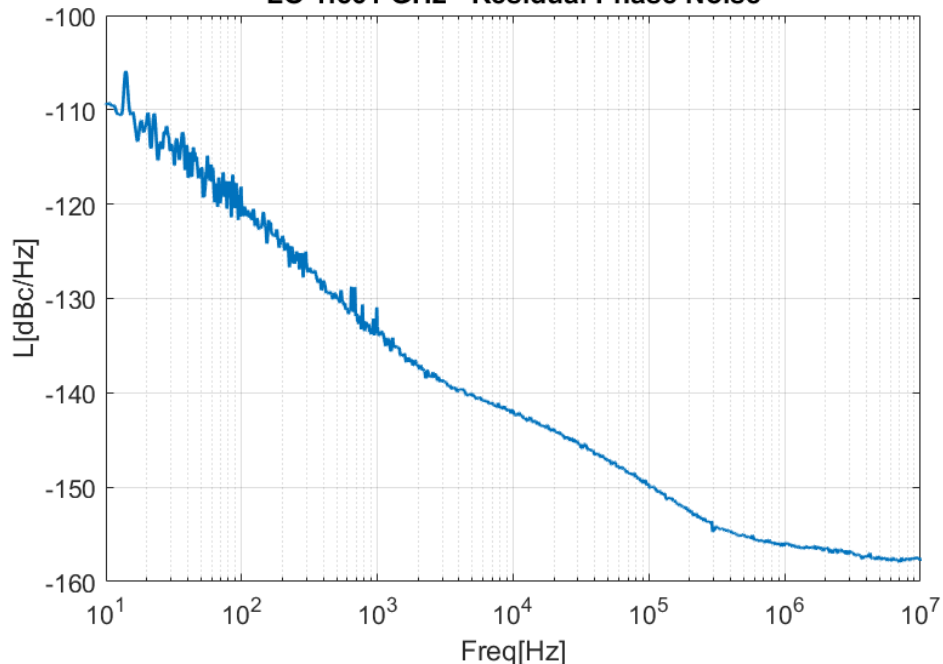
Range	Trace	Start Offset	Stop Offset	Weighting	Int Noise	PM	FM / AM	Jitter
1	1	10.000 Hz	1.000 MHz		-91.12 dBc	2.25 m°/39.32 μrad	11.148 Hz	4.622 fs

RF Performance

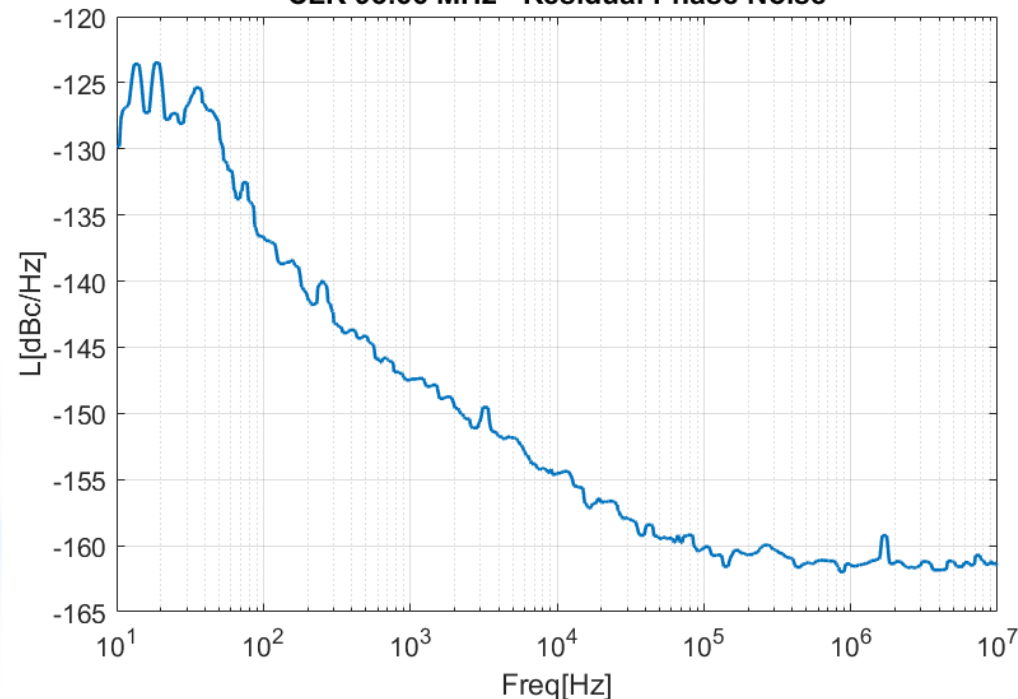
DeRTM-LOG 1.5 GHz:

- REF 1.500 GHz
- LO 1.561 GHz
- CLK 93.66 MHz

LO 1.561 GHz - Residual Phase Noise



CLK 93.66 MHz - Residual Phase Noise



Measurement results provided by U.Mavrič (MSK, DESY)

Test-Stand

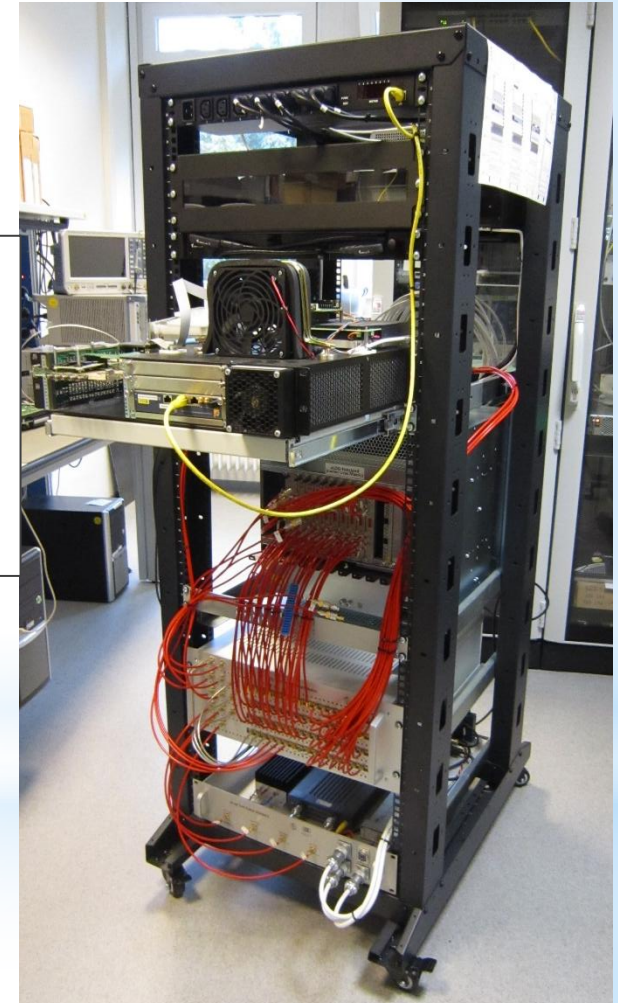
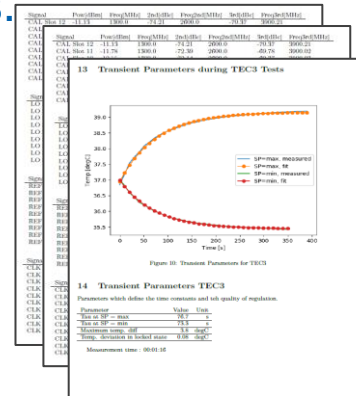
A fully automated test stand developed and provided by DESY to check possible production errors.

➤ Measure:

- individual mezzanines (DC/DC mezz., RF mezz., ...)
- A fully assembled module

➤ Test:

- CLK frequency [1 MHz to 500 MHz]
- LO, REF and calibration signals [1 MHz to 6 GHz]



Production and Future Development

Available Options: DeRTM-LOG 1.3 GHz and 1.5 GHz
Working on 3 GHz



Further developments by DESY with new architecture

- Cover various LO and CLK generation scenarios
- Cover more REF frequencies applications
- Residual phase noise of the LO and CLK generation
 ≤ -165 dBc/Hz white noise

We provide DeRTM-LOG for your frequency application.

Thank you for your attention!

Thanks to DESY colleagues for their support.

Further questions, please contact us.

Email: jbai@kvg-gmbh.de