Innovative Suspended Quartz Structure Offers High Stability Reference Clocks

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Topics

High stability crystal types

QAS crystal

Improvements

- Stability
- Vibration

Solutions for Out-of-the-box 24-hour holdover

QAS vs Classic QAS Crystals

Holder Crystal - crystal in a protective housing with electrical terminals

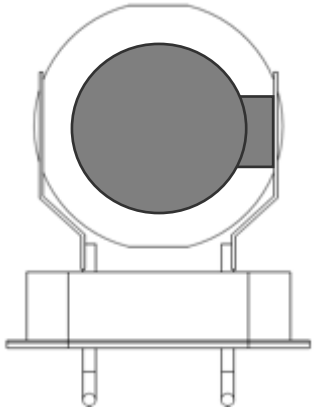
- Mechanical protection - for the quartz crystal
- Stable environment - isolation from thermal and mechanical stresses
- Electrical connectivity - through leads

Classical QHS electrodes

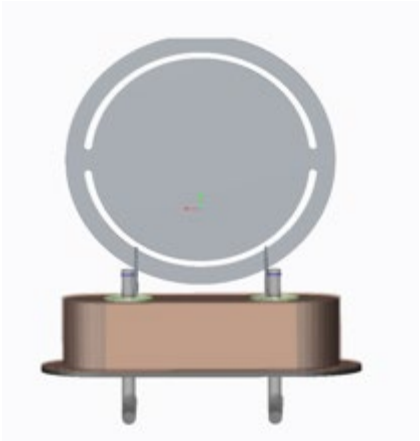
(Quartz High-Stability)

Quartz Auto Suspendu (QAS) design

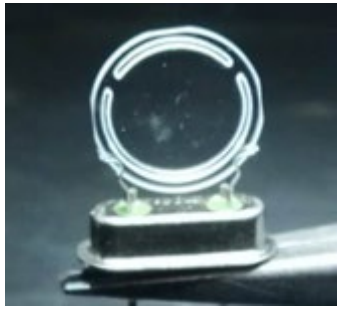
Translates to Self-suspended Quartz

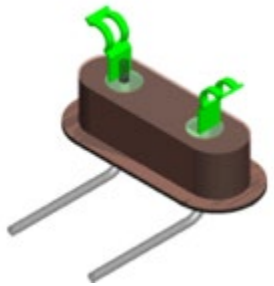


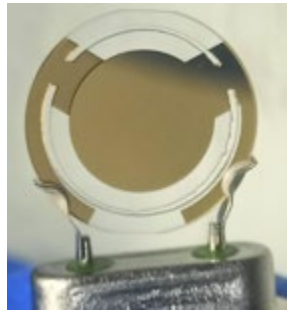
QHS



QAS







Comparison of performances

The HC-43 packaged crystal is placed inside an OCXO of typical Stratum 3E+ performance

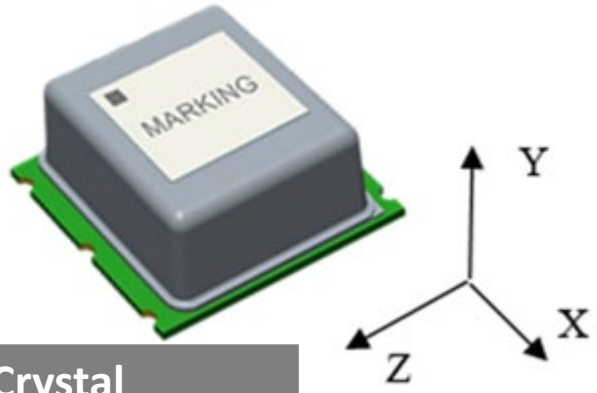
- 1ppb temperature stability
- 0.3ppb/day ageing

Note: Stratum 3E is 10ppb pk-pk and 1ppb/day ageing

Performance comparison with

- Temperature stability
- Phase Noise
- Ageing
- Re-trace
- Acceleration sensitivity
- Holdover

Performances Comparison QHS and QAS



A 25x22 mm - sized OCXO device is similar

The frequency versus temperature

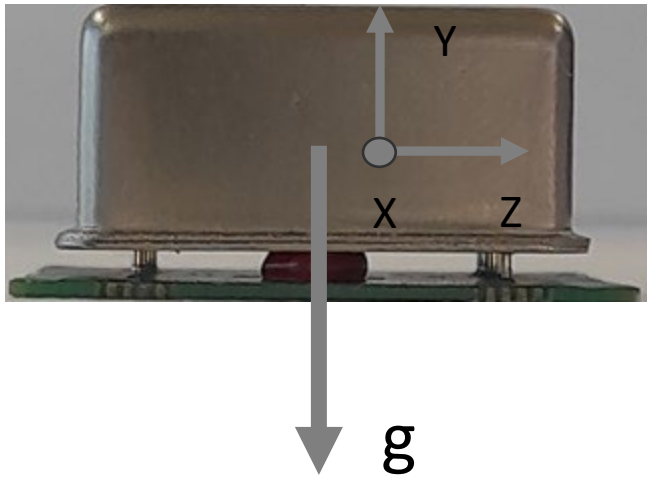
Parameter	Condition	QAS Crystal	QHS Crystal
Frequency Vs Temperature (DF/F)	-40°C to 85°C	< 1E-9	< 1E-9

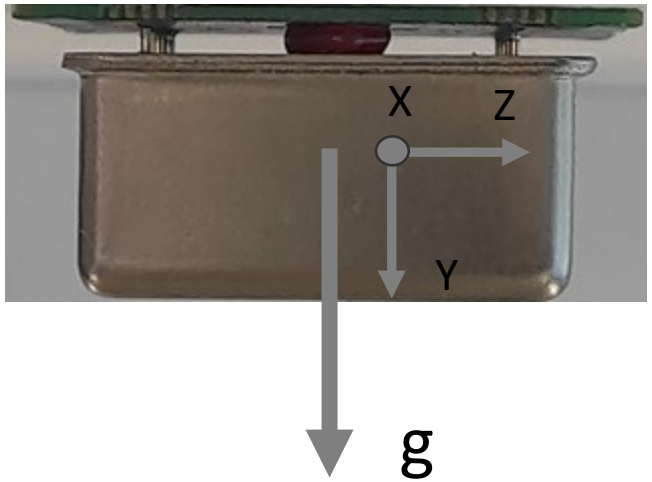
The phase noise

Parameter	Offset	QAS	QHS
Phase noise	1 Hz	-90	-90
(dBc/Hz)	10 Hz	-120	-120
	100 Hz	-140	-140
	1 kHz	-150	-150
	10 kHz	-155	-155
	100 kHz	-160	-160
	1 MHz	-165	-165

Acceleration sensitivity Comparison

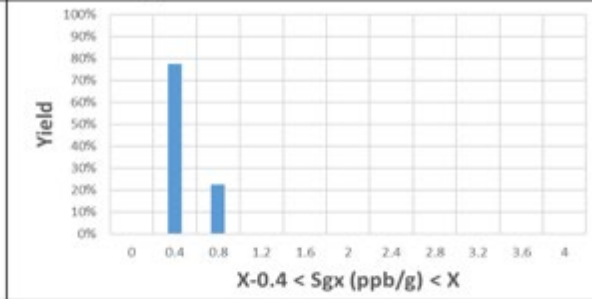
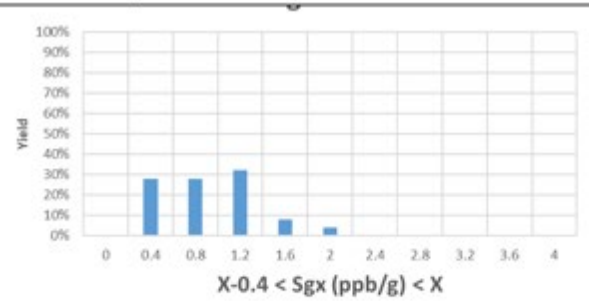
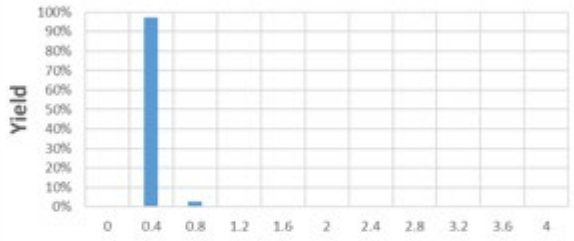
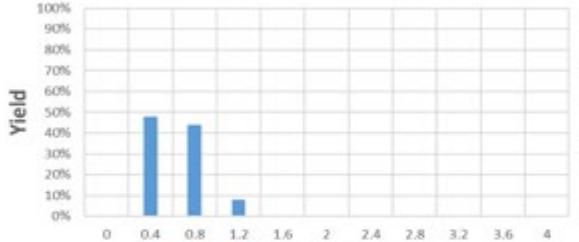
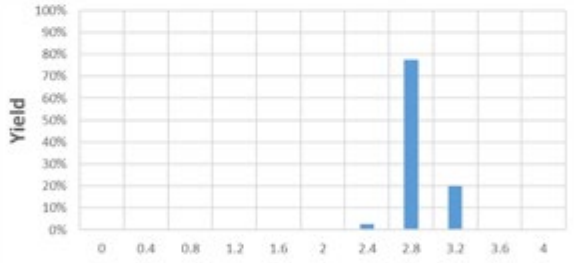
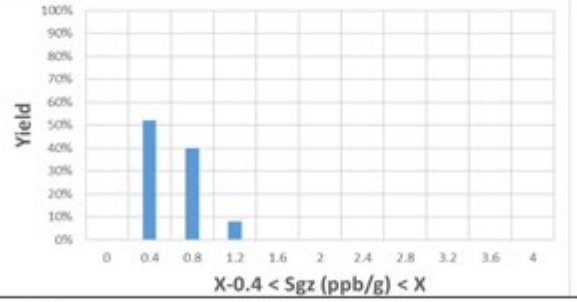
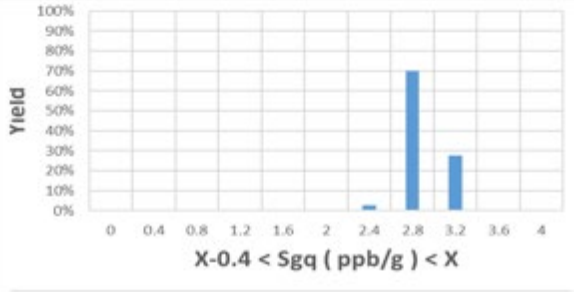
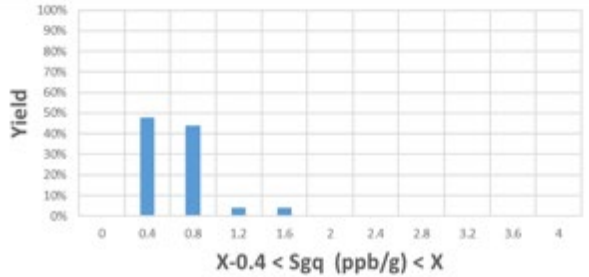
Based on the 2g tip over testing method





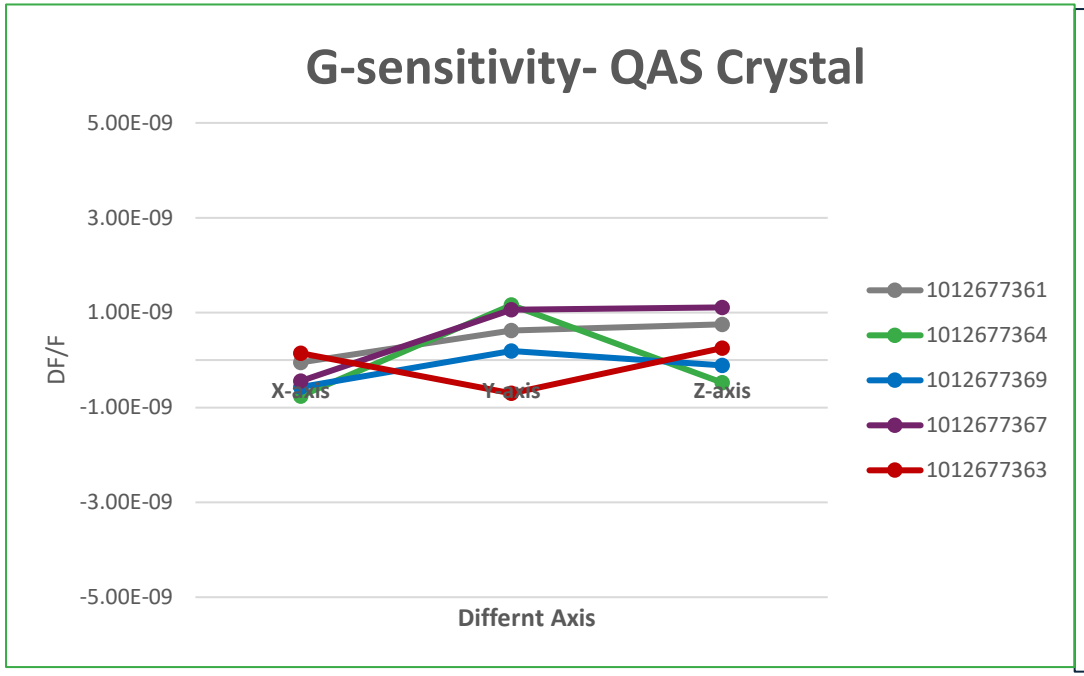
- Calculation of Sgy, Sgx and Sgz in DF/F /g
- The total sensitivity, Sgq:
  - $Sgq=\sqrt{Sgx^2 + Sgy^2 + Sgz^2}$.

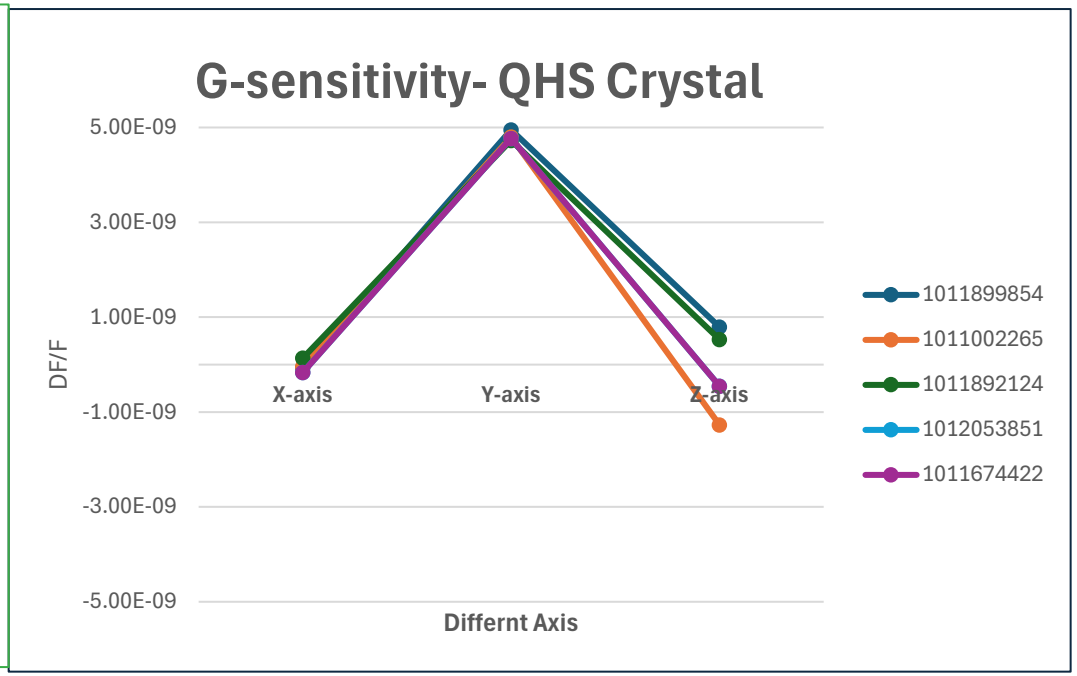
Acceleration sensitivity measurements

	HC43 QHS	HC43 QAS
X axis		
Y axis		
Z axis		
Overall		

Acceleration sensitivity measurements

The acceleration sensitivity is 3 times better than the traditional crystals to <1ppb/g





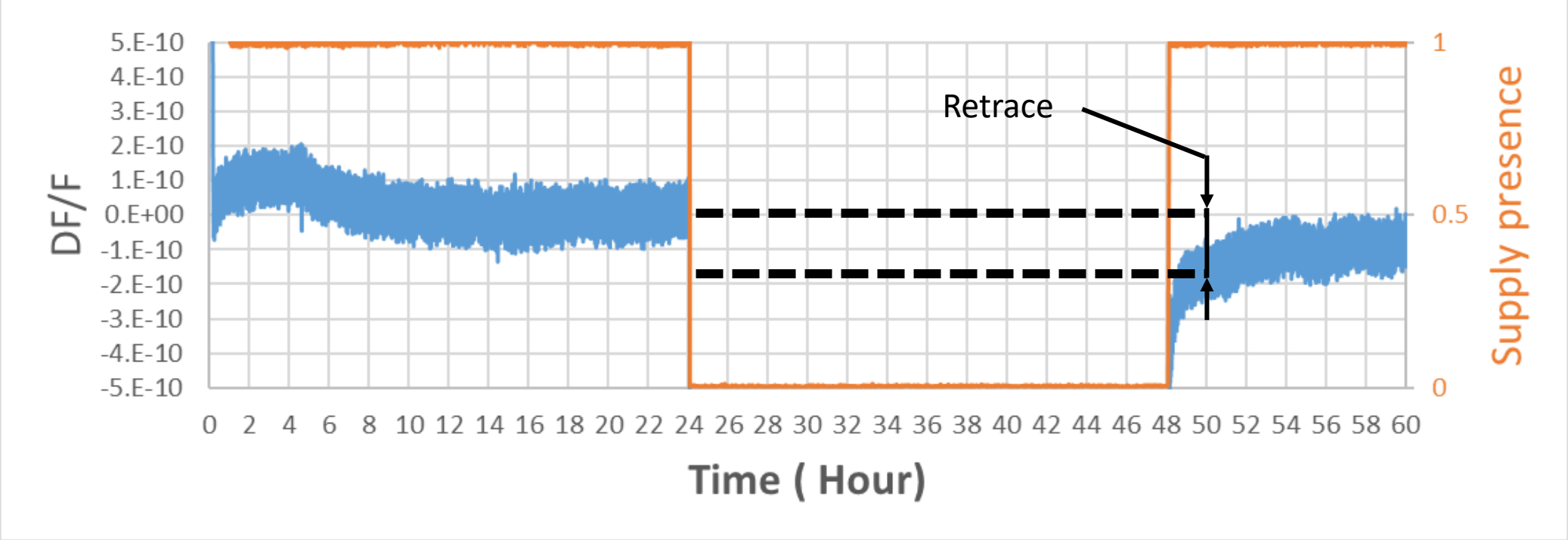
Acceleration values on various environments

Environment	Max Acceleration (g)	Dominant Frequency Range
Data Center	~0.05 g	5–100 Hz
Office Server Room	~0.05–0.1 g	5–100 Hz
Tower Base Station Outdoor Room	~0.05–0.1 g	<10 Hz
Telecom Pole (Mast) Top	~0.2–0.3 g	1–10 Hz
Near Railway Line	~0.15 g	5–30 Hz
Onboard Train (Acceleration Phase)	~1–3 g peak	5–60 Hz
Onboard Train	~0.5 g (rms)	5–50 Hz
Onboard Aircraft (Take-off/Climb)	~0.5–1.5	10–300 Hz
Onboard Aircraft (Cruise)	~0.2 g	20–500 Hz
Onboard Missile / Launch Vehicle	8–20 g (rms/peak)	20–2000 Hz

10MHz QAS Retrace after 24H off

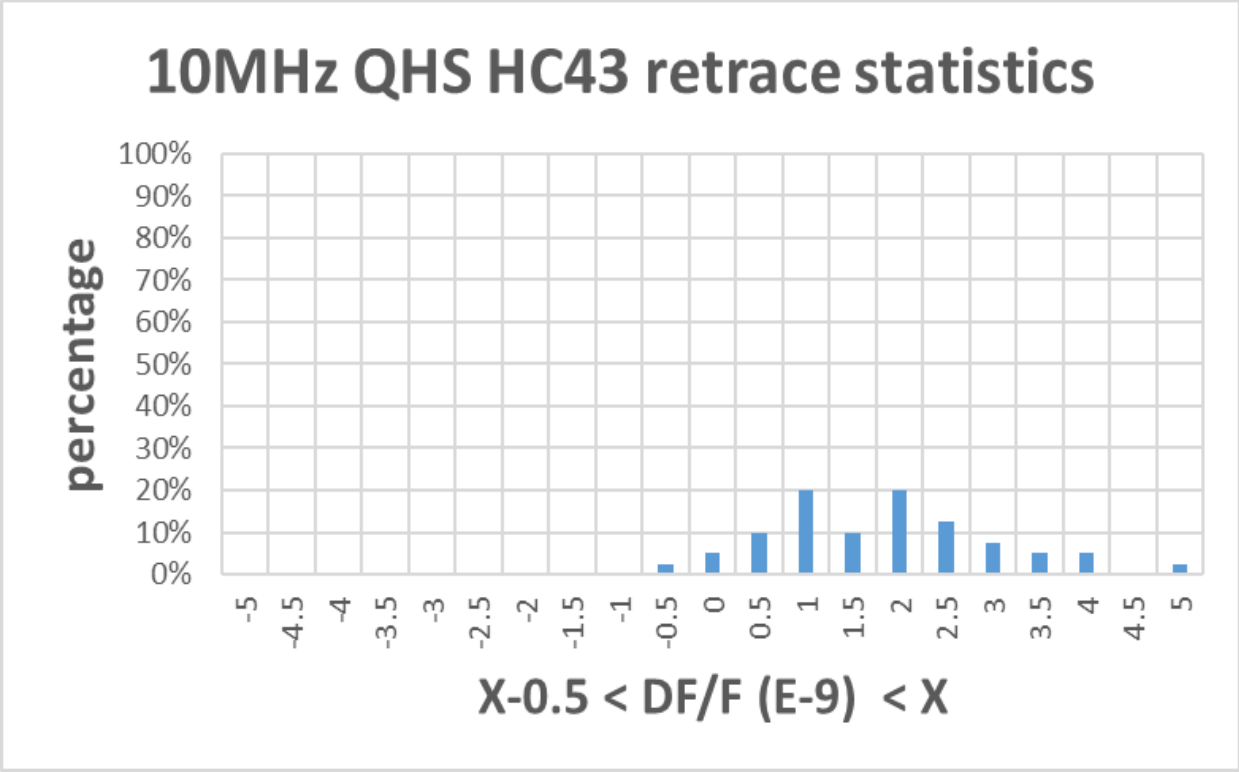
Relative frequency difference between

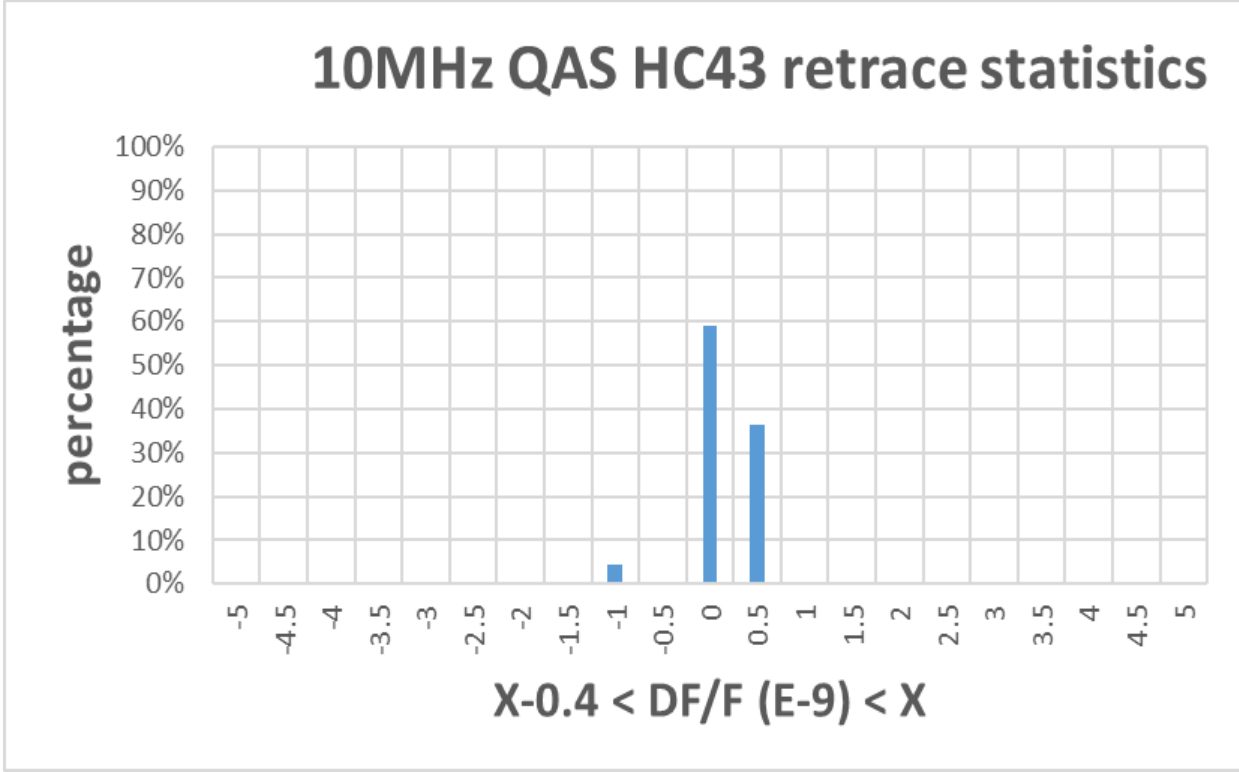
- the frequency after 24H off and just before the switch off



The retrace is 10 times better than the traditional crystals

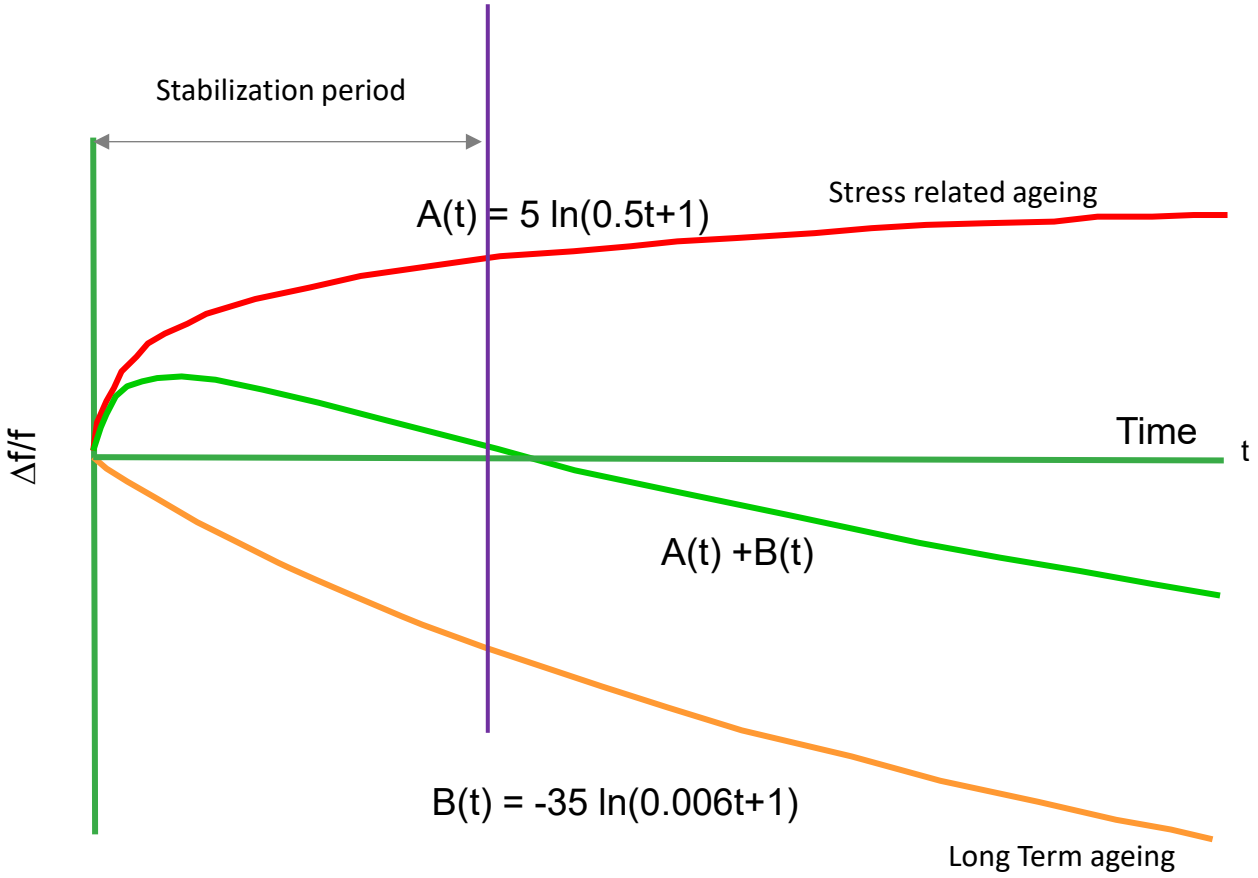
QAS retrace is 10x better





Ageing

Systematic frequency change over time



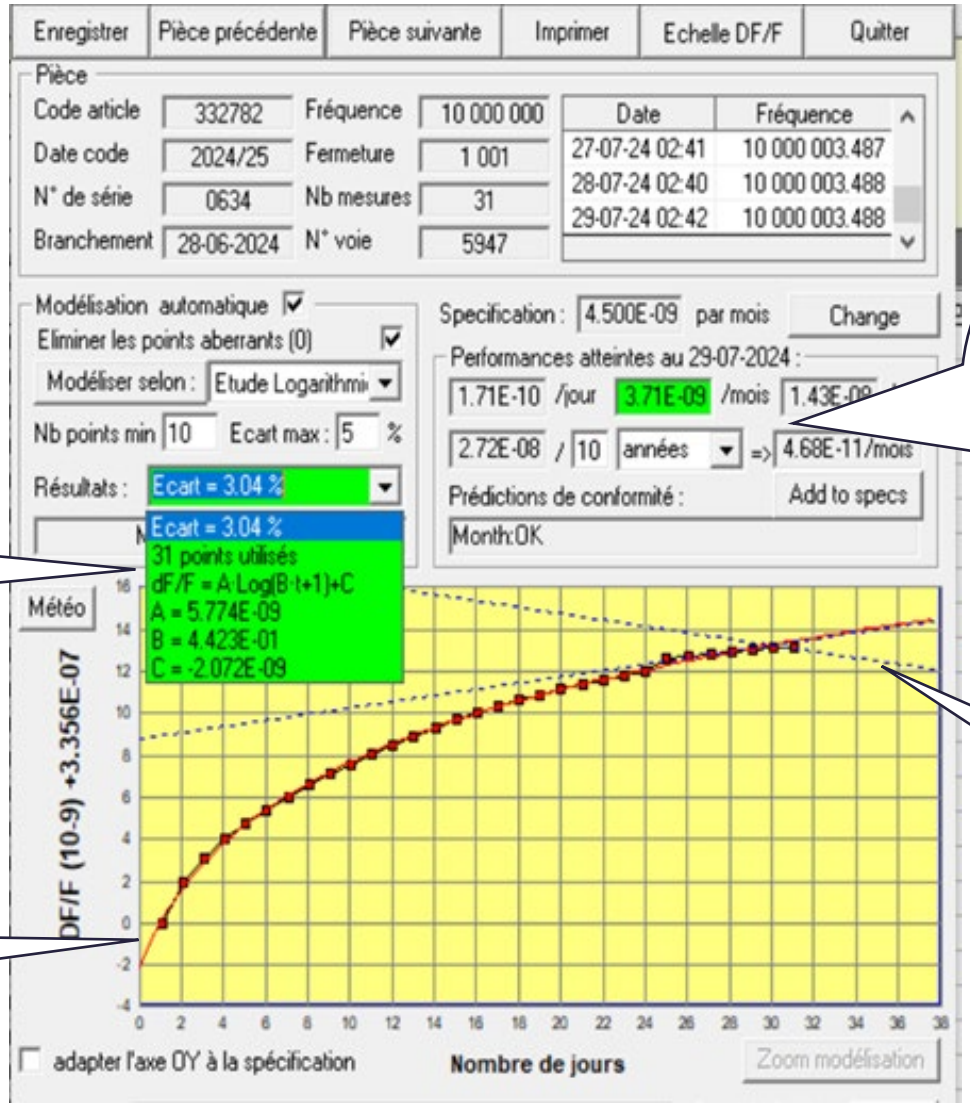
Projection of the frequency ageing

Minimally 10 points

- 1 point per day

Until target ageing achieved

- Per day, month and years



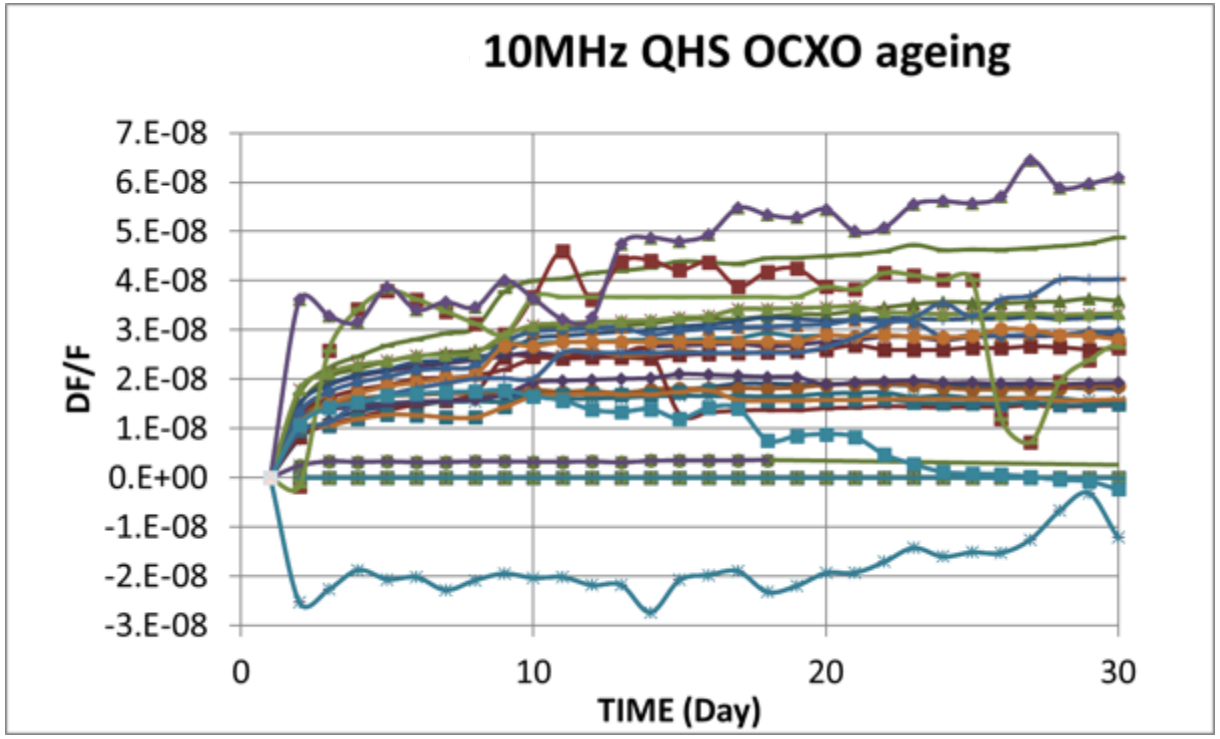
Use of Aging model & calculated Coefficients

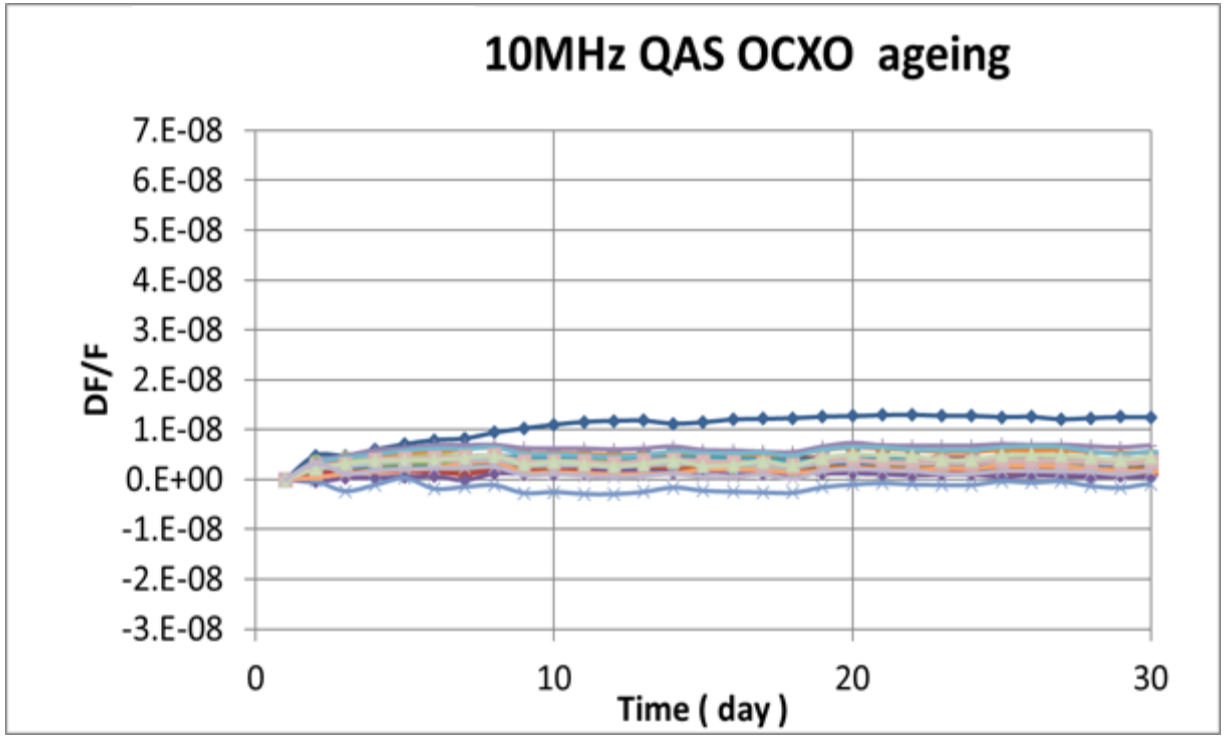
Measured Ageing per day, Predicted per month, per year & 10/20 years

Red line – curve fitting w.r.t Aging Model on the Measured data

Blue line – Prediction curve

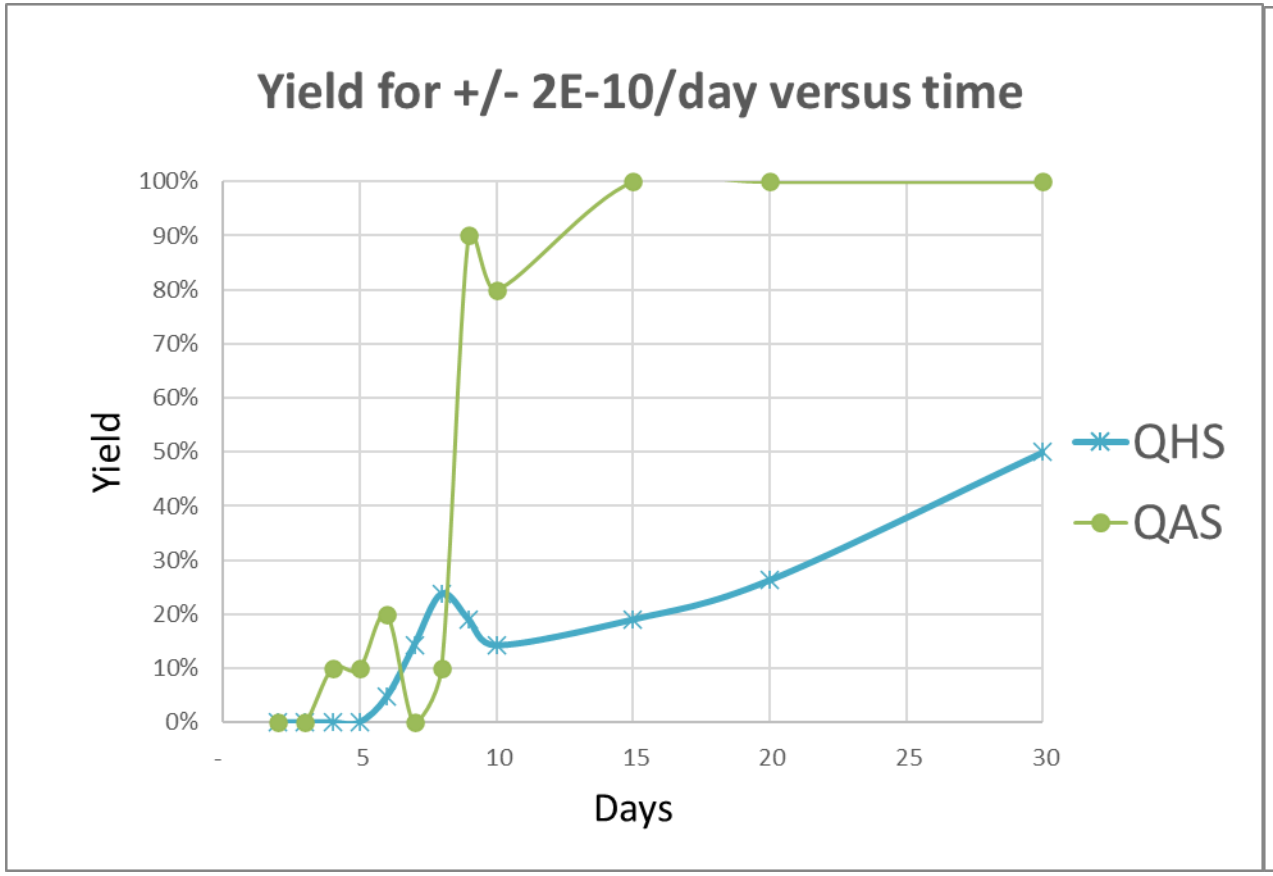
10MHz QAS vs QHS Ageing

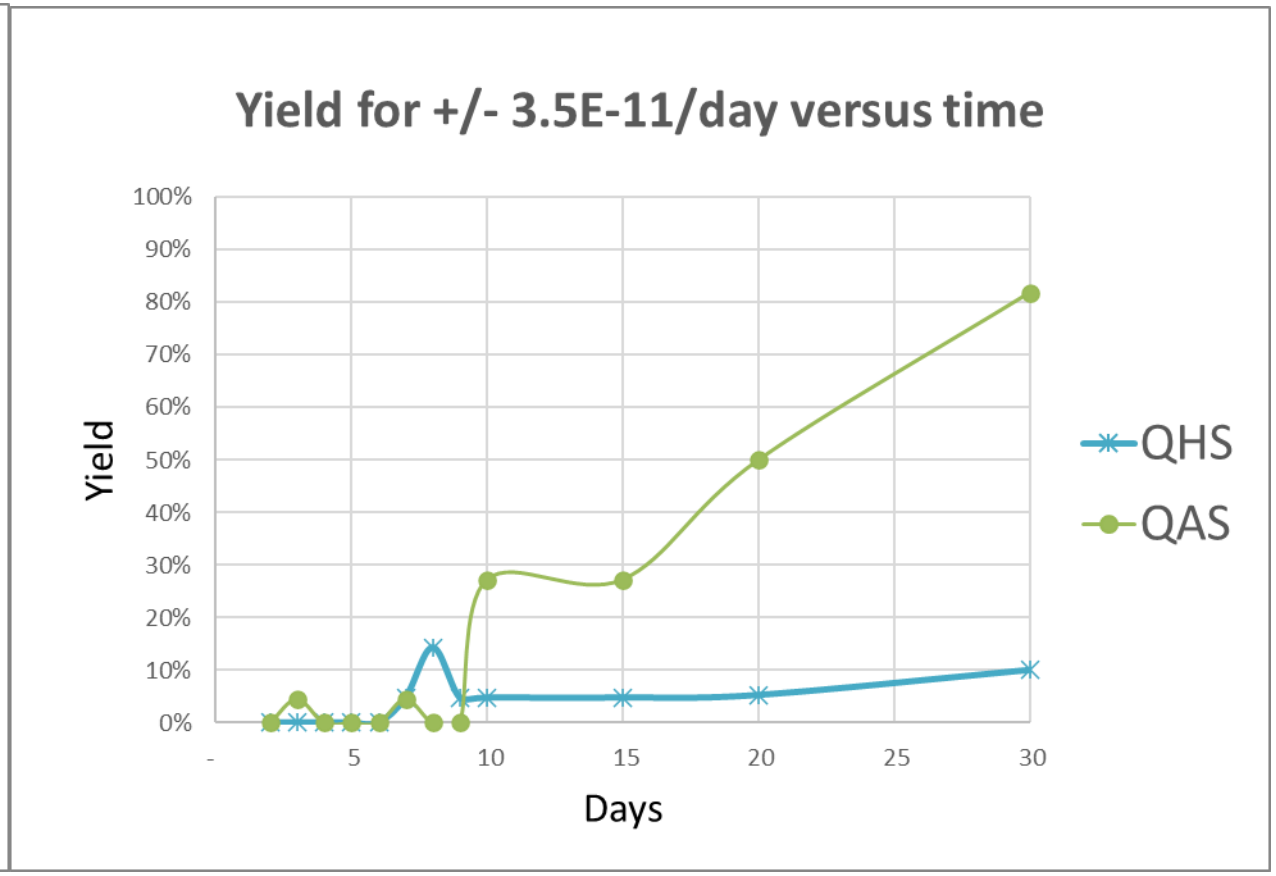




The ageing is 5x better with QAS

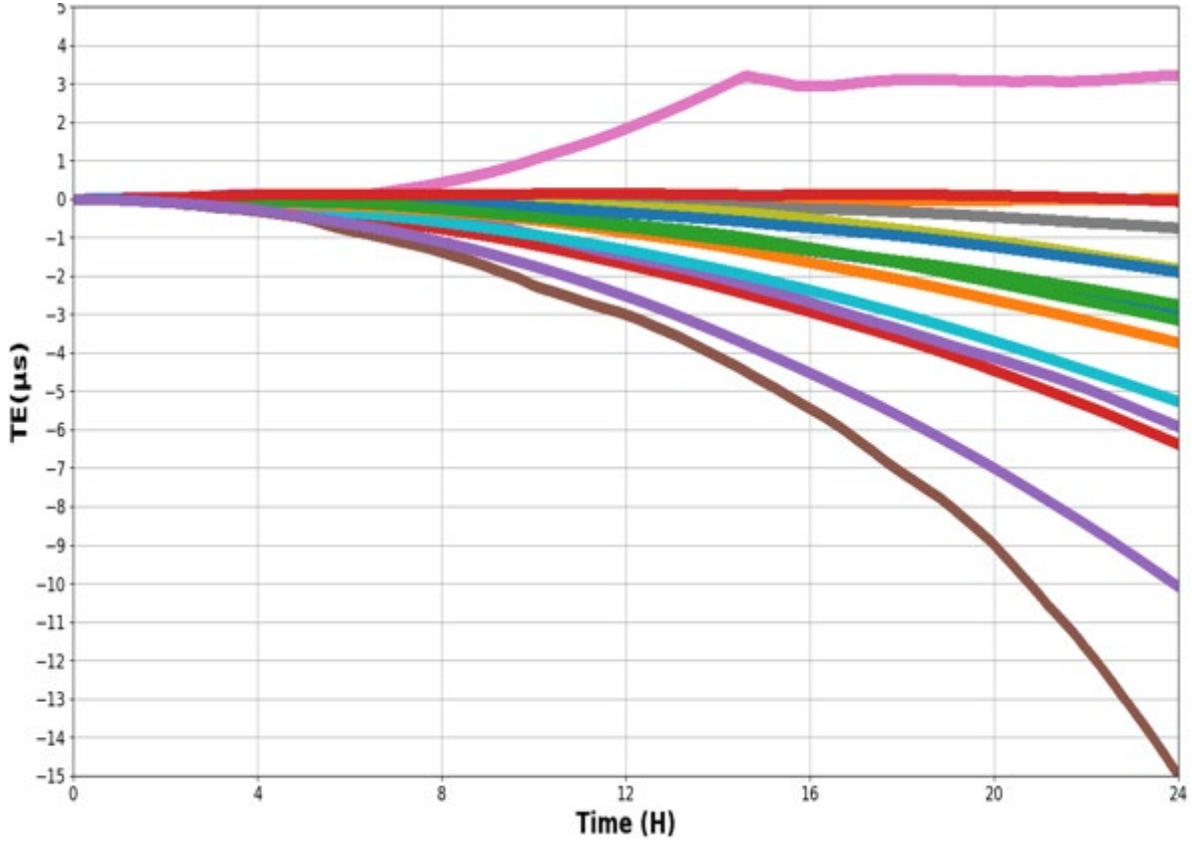
10MHz Daily Ageing



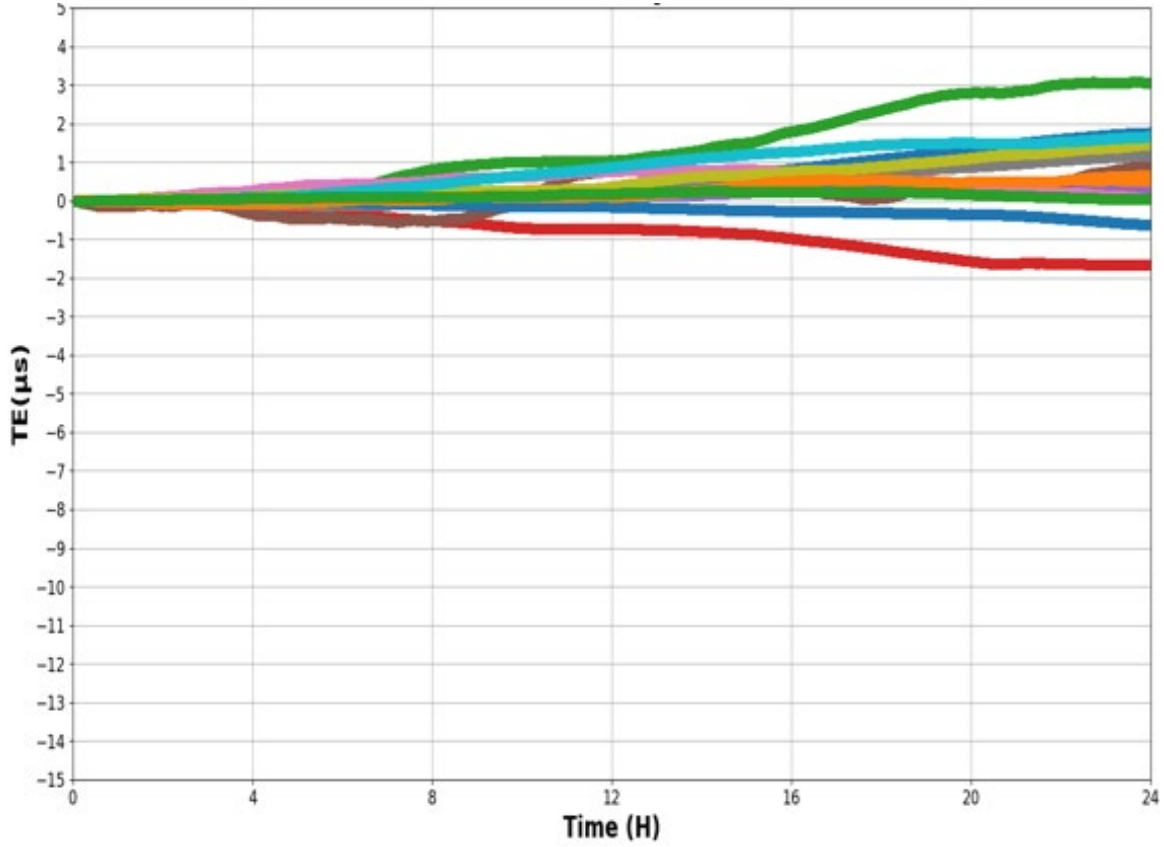


The daily ageing time to reach 2e-10 is five times shorter for the QAS.
The total number of devices that exceed a certain ageing threshold is higher

Holdover performance

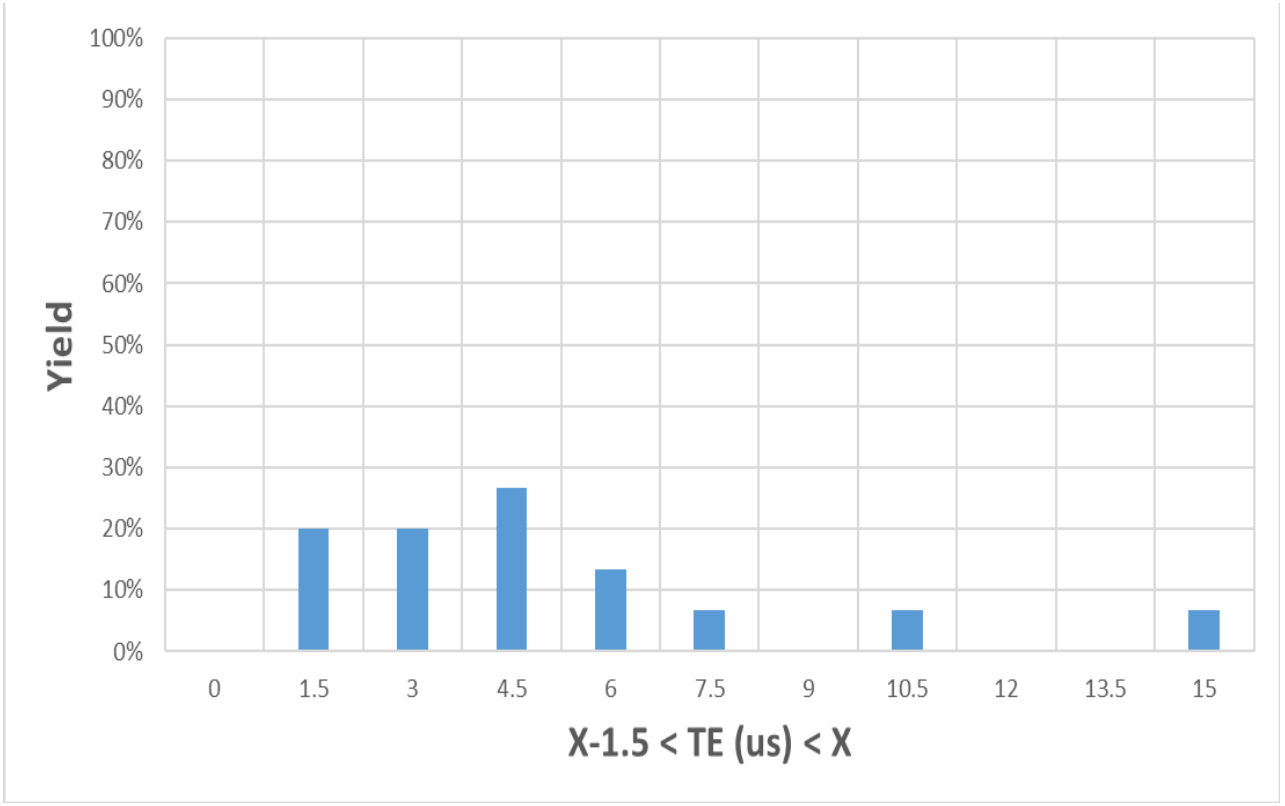


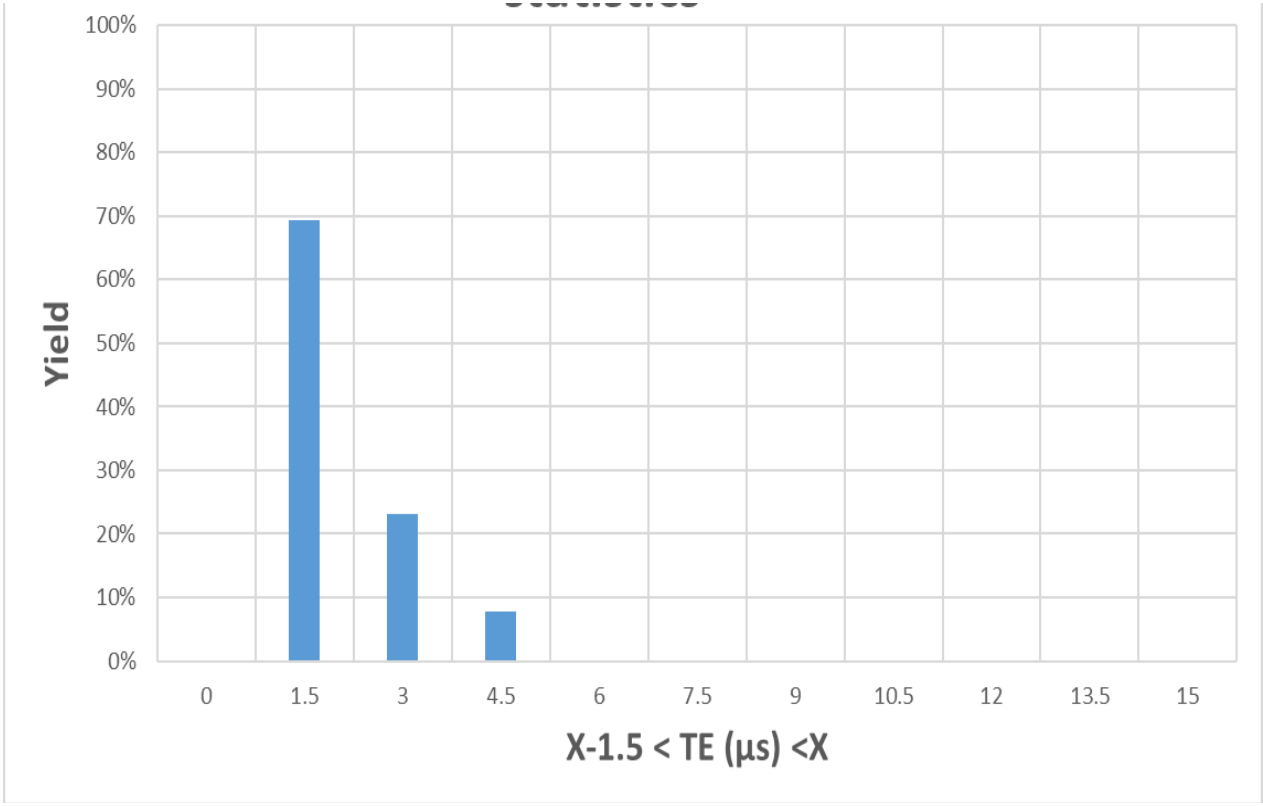
QHS



QAS

Holdover performance (10MHZ) – Distribution across batches

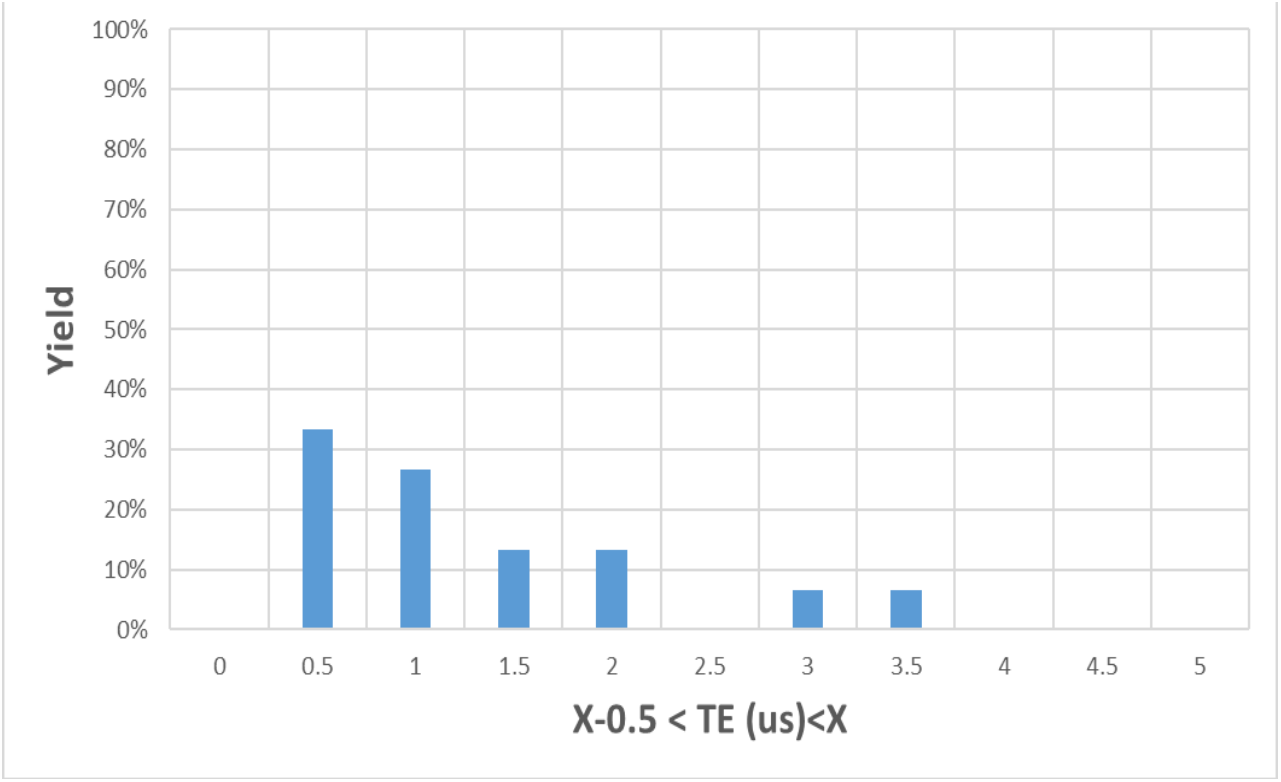


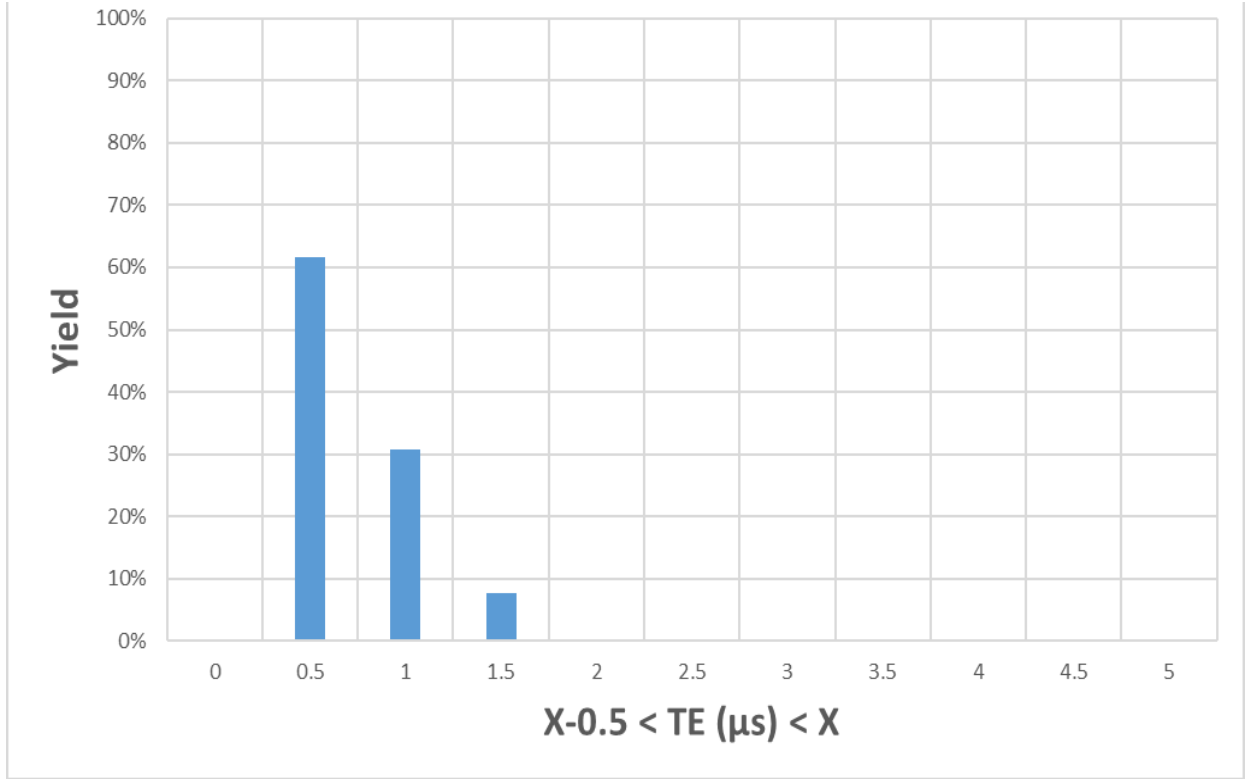


The 24-hour (1.5uS) yield for the holdover is over 70% with QAS for a certain ageing time

Holdover on 10MHz 25x22 OCXO

The holdover over 12h for 1.5us is with a yield of 100% for the QAS on certain ageing period





Summary

- QAS structure is less affected by mounting stress compared to QHS.

  Overall improvement with out-of-the-box holdover
- QAS has

  3× lower acceleration sensitivity (<1E-9/g)

  10× better retrace (<5e-10) is than traditional

  5× smaller frequency deviation (1e-8) than traditional

  5× faster to reach a daily ageing rate of 2e-10/day than traditional

  daily ageing (±3.5e-11) meets the 5G holdover requirement (1.5µs over 24h) in 80% of cases.

- No ageing compensation needed to meet 5G holdover.

Thank you!

Contributions from:

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Manager/Design

Thank you