Low phase noise (PN) master oscillator (MO) generation and distribution for ALS and ALS-U

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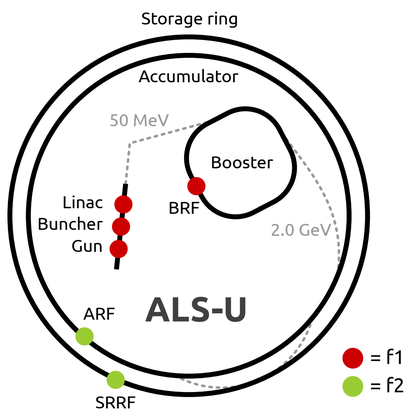
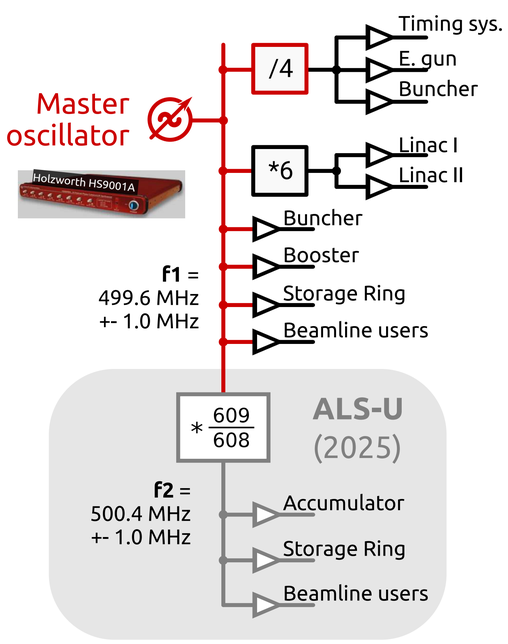
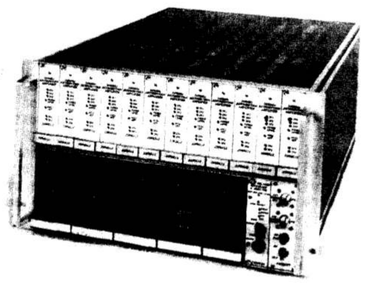
ALS-U MO distribution overview



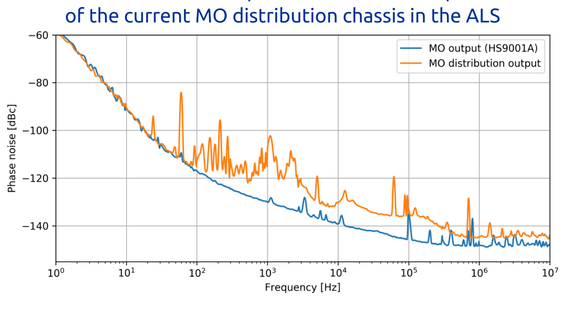


Current state in the ALS

* Distribution over phase stable coax
  Andrew LDF4-50A Heliax (16 PPM/K)
* Distribution chassis (x12) based on **obsolete** RF power amp. modules
* Operational since 1989, **highly reliable**
* More channels needed!
  e.g., for beamline users
* Workarounds with RF splitters have caused trouble in the past
* Only single frequency compatible
* Phase noise / signal quality bottleneck

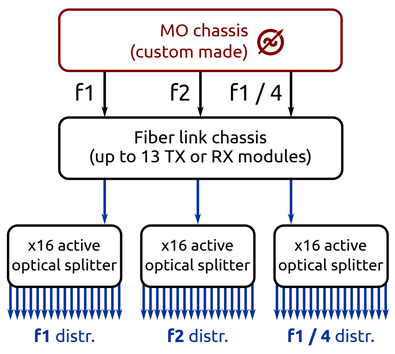


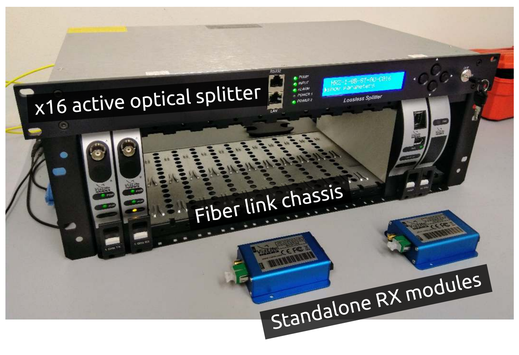
Phase noise and spurs at the in- and output of the current MO distribution chassis in the ALS



Commercial RF over fiber link (ViaLite)

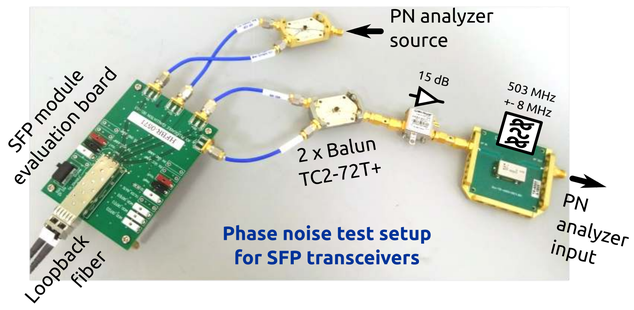
* good candidate for future MO dist.
* designed for satellite communication / TV broadcast industry
* redundant power supplies
* hot-plugable modules (blind mate con.)
* telemetry and alarms over ethernet
* **active optical x16 splitter available**
* standalone receivers available
* excellent phase noise performance
  see brown trace in PN plot

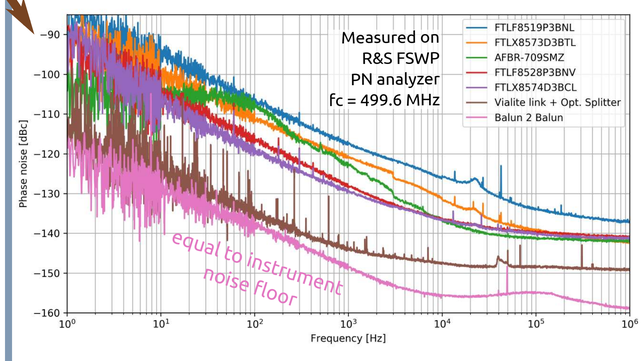




An experiment with SFP transceivers

* extremely low cost & wide availability
* usable from 500 kHz to 1.5 GHz (-5 dB)
* surprisingly good PN / spur performance!





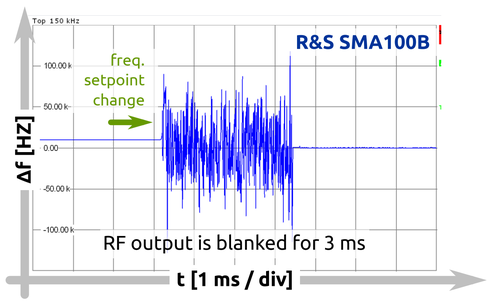
Device	Gbps	Gain [dB] (499.6 MHz)	RMS Jitter [fs] (1 Hz .. 1 MHz)
FTLF8519P3BNL	2.125	1.0	103
FTLX8573D3BTL	10	-1.2	60
AFBR-709SMZ	10	-2.8	50
FTLF8528P3BNV	8.5	0.6	49
FTLX8574D3BCL	**10**	**-0.7**	**47**
Vialite + optical splitter		-0.5	17
Baluns only (TC2-72T+)		-2.0	6

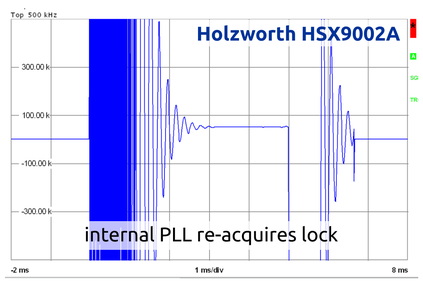
ALS Master Oscillator

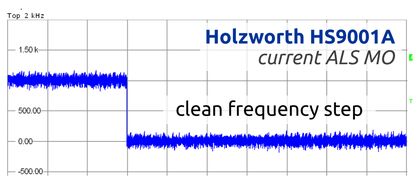
f_1 = 499 645.0 kHz

* Annual freq. variation: **< +- 10.0 kHz**
* Chroma. meas. *ΔP = 0.45%*: **< +- 2.0 kHz**
* Insertion devices: **< +- 0.1 kHz**

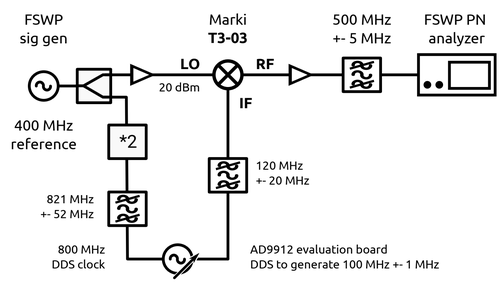
needs to be adjustable in 1 mHz increments at 1 Hz update rate (slow orbit feedback) **without phase discontinuity**

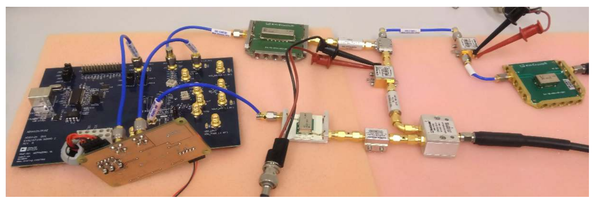






Homebrew I: *AD9912 DDS + Mixer*





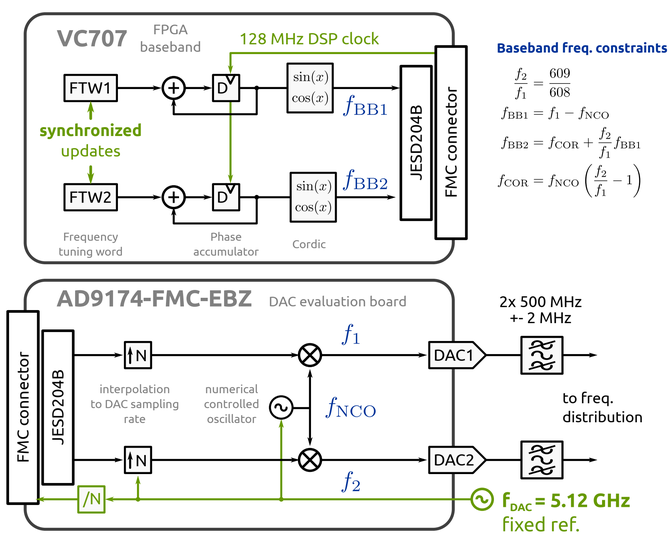
A clean fixed 400 MHz frequency reference is split in two channels. One is used as clock for a DDS chip (AD9912), generating an adjustable frequency of ~100 MHz. The other one is used as Local Oscillator for a mixer, to up-convert the variable ~100 MHz to ~500 MHz

* **Extremely low phase noise**

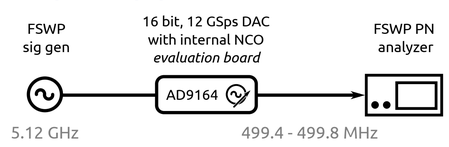
* Abandoned due to **significant spurs** at sensitive frequencies
* They move with frequency set-point and hence are **hard to control**
* Spurs inherent to the **limited DAC resolution** of the AD9912 (14 bit)

Homebrew II: *Direct synthesis with a modern DAC*

Setup for ALS / ALS-U dual frequency generation



Setup for PN / spur measurements



AD9164 / AD9174 DACs are capable of directly synthesizing the MO signal with excellent phase noise performance

less spurs due to higher resolution (**16 bit**) and sampling rate (**up to 12.6 GSps**) of the DAC compared to AD9912 (14 bit, 1 GSps)

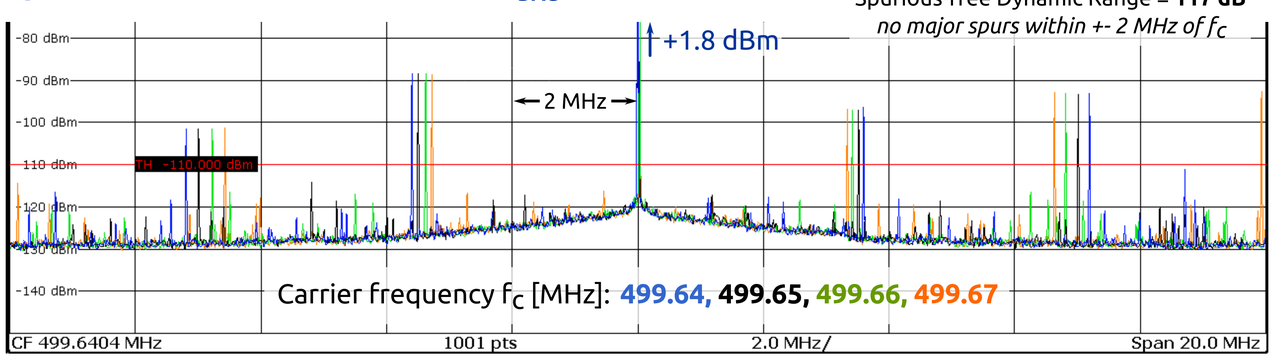
AD9174 = **2 independent DACs** for ALS / ALS-U dual frequency generation

DAC sampling rate f_{DAC} chosen to keep major spurs out of ALS operational frequency range

Basically no spurs below 2 MHz offset!

Spur measurement of AD9164 at f_{DAC} = 5.12 GHz

for f_c = 499.4 ... 499.8 MHz:
Spurious-free Dynamic Range = **117 dB**
no major spurs within +- 2 MHz of f_c



PN measurements of 3 MO candidates