‚Status of the multichannel down-converters‘

F.Ludwig, M. Felber, M.Hoffmann, S.Simrock, H.Schlarb / DESY

Content :

1. Overcome down-converter limitations
2. Gilbert-cell and passive mixer prototypes
3. Multichannel packaging
4. Test setup for down-converter characterization
5. (Phase noise budget at FLASH – optional)

‚Status of optical to RF converters‘

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J.W.Kim, J.Burnham, J.Chen, D.Cheever, F.X.Kärtner / MIT

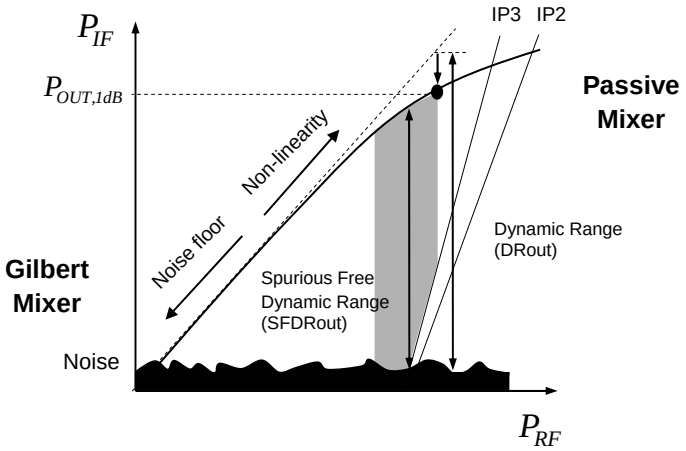
Content :

1. Direct photodiode detection
2. Injection locking
3. Sagnac loop

Supported by the EUROFEL project.

Overcome down-converter limitations from noise

- **Compromise between noise and linearity :**

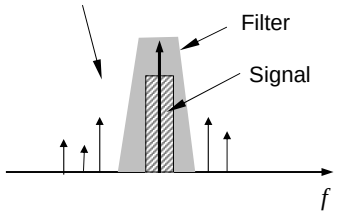


- **Parameters of some different mixers:**

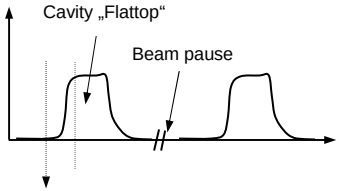
		LT5522	ADL5350	LT5527	HMJ7	HMJ7-1	AD8343
P(RF)	dBm	-7		-5	-10	-10	-12
P(LO)	dBm	-5	4	-3	21	21	-10
P(IF)	dBm	-7,1			-18,5	-18,5	-4,9
NF	dB	13,2	6	12,4	8,5	10,5	14,1
OIP3	dBm	23	20	27,5	23,5	25,5	23,6
out,1dB	dBm	8,1	11	10,3	13,5	14,5	8,9
Gain	dB	-0,4	-6	2,3	-8,5	-8,5	7,1
i. RF to IF	dB		23		24	24	29
i. LO to RF	dB	50	15	55	24	24	52
i. LO to IF	dB	49	21	70	30	30	54
IF(min)	MHz	0,1	200		10	10	0
B=10MHz							
MDSin	dBm	-87,78	-94,977	-88,577	-92,5	-90,48	-86,88
DRin	dB	96,28	111,98	96,577	114	113,5	88,68
MDSout	dBm	-87,38	-88,977	-86,277	-84	-81,98	-79,78
DRout	dB	95,48	99,977	96,577	97,5	96,48	88,68
SFDRout	dB	73,58	72,651	75,851	71,7	71,65	68,92

- **Filtering of distortions :**

Signal distortions :
- intermodulation effects (IP3)
- higher harmonics (IP2)



- **Off beam phase calibration :**



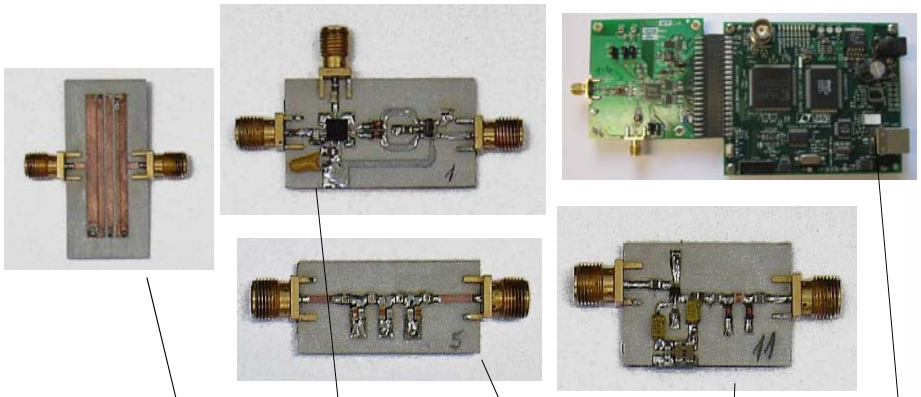
Calibration of the down-converter phase using a local rf-reference.

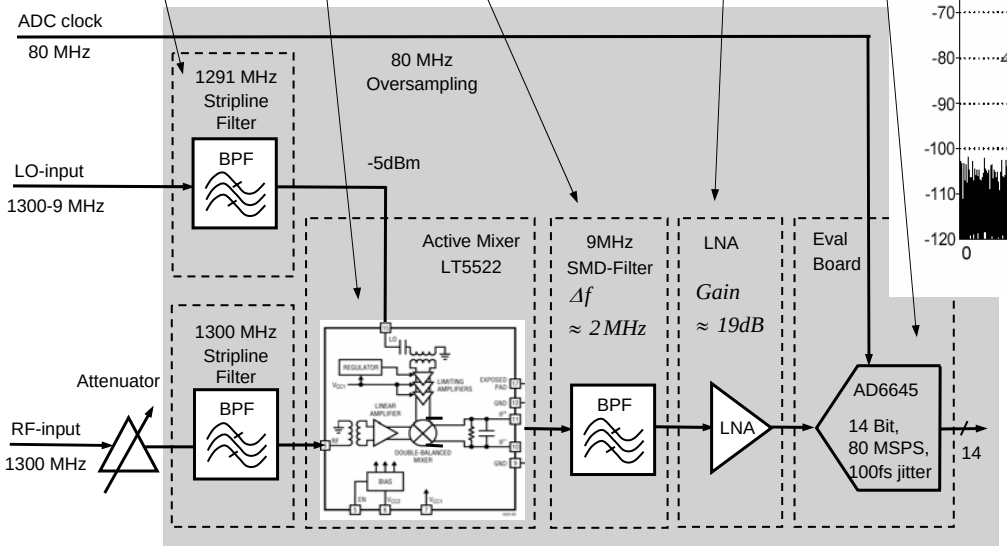
System can only drift for 1ms!

FNAL LLRF Workshop, Chicago 2006, F.Ludwig et.al.“Multichannel down-converters for the XFEL“

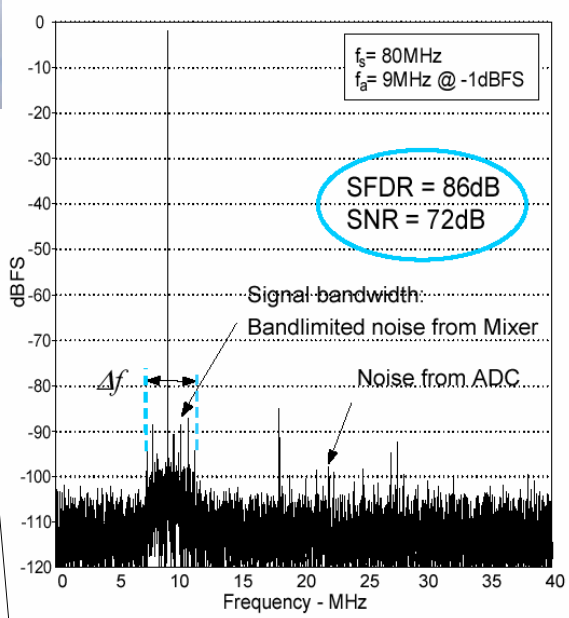
- Filtering of distortions using a modulation scheme with a CW-LO signal.
- Increase the mixer input power and calibrate or linearize the down-converters characteristic during the beam pause !

Gilbert-mixer prototype for a CW-modulation scheme





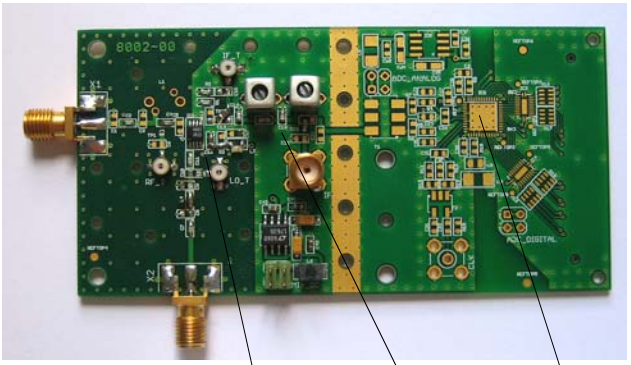
- **SNR for oversampling :**

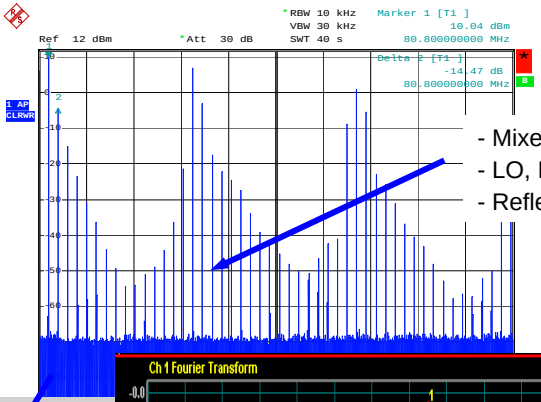


SNR is limited to 72dB by the NF of the front end mixer.

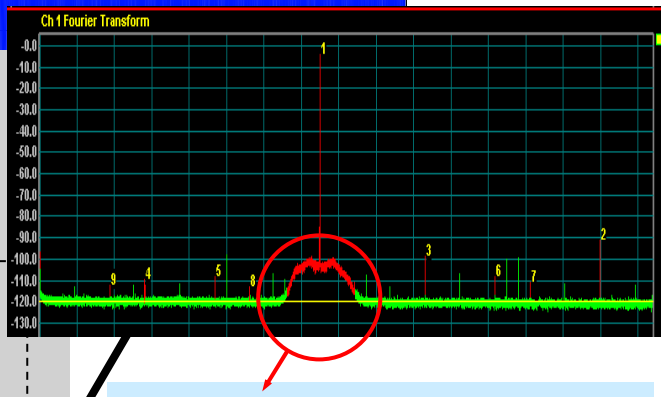
(SNR of about 70dB from JLAB using HMJ mixers.)

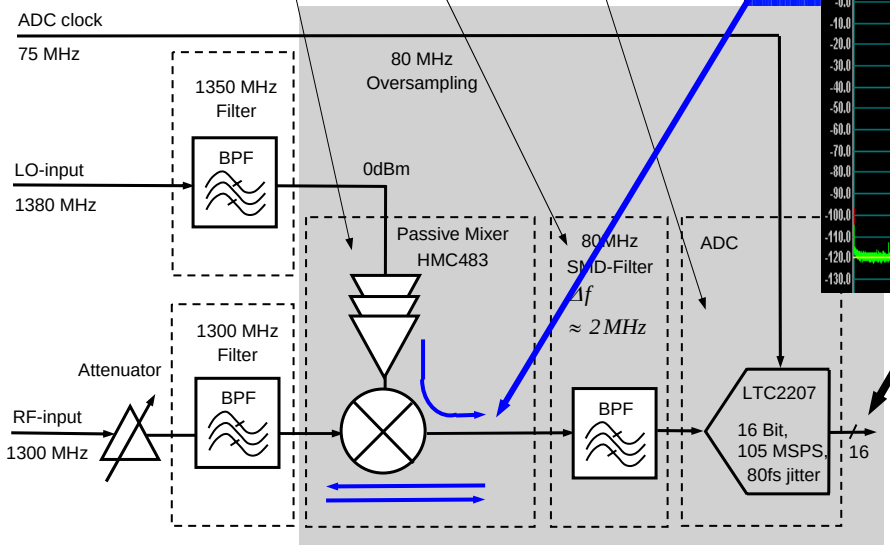
Passive-mixer prototype for a CW-modulation scheme





- Mixer non-linearities
- LO, RF, IF leakage
- Reflections

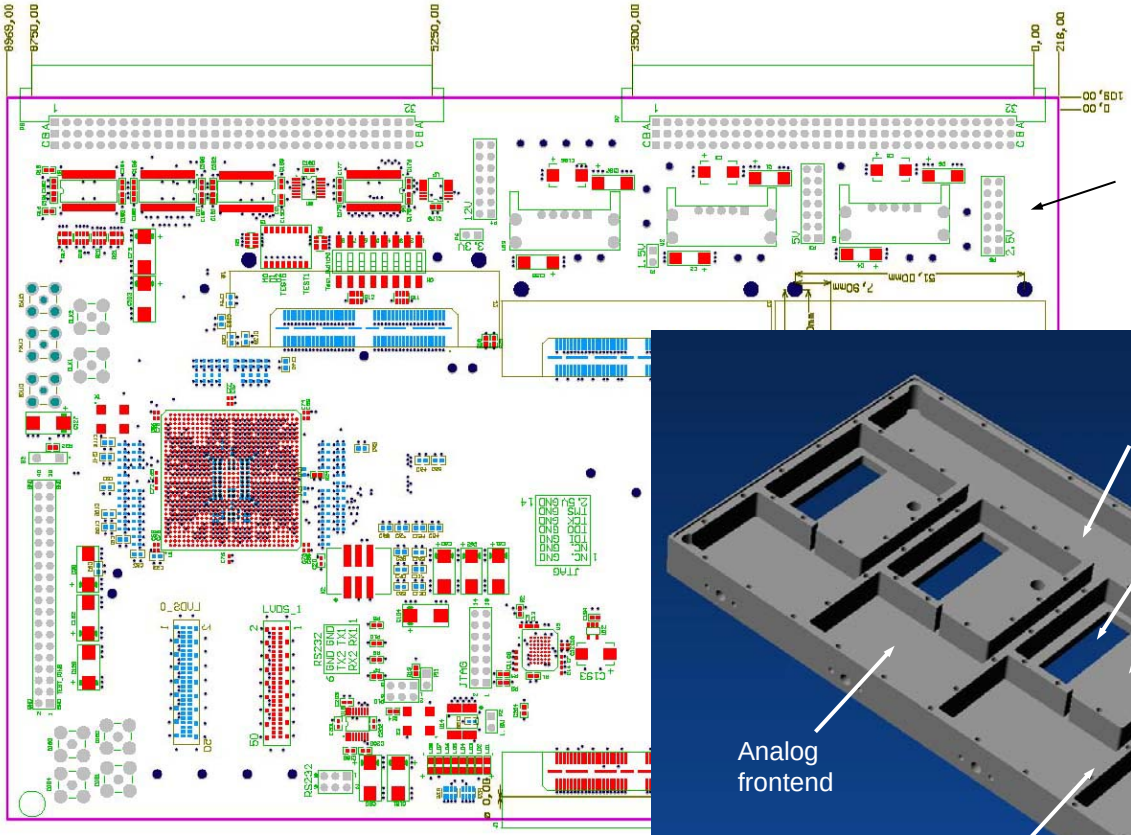




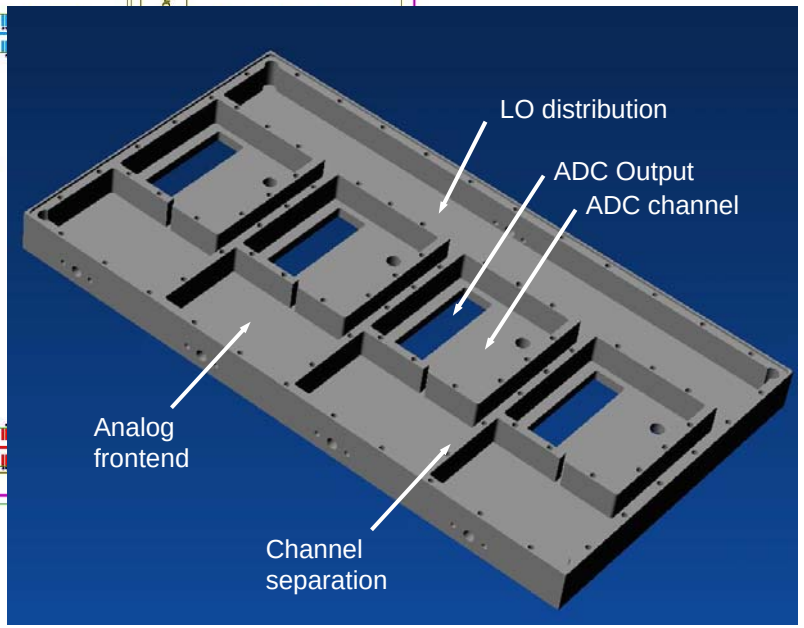
- SNR of 73dB is limited by the reference signal generation of RF and LO.

- Test setup with fs resolution.
- Diplexer design to reduce distortions.

Packaging of the down-converter



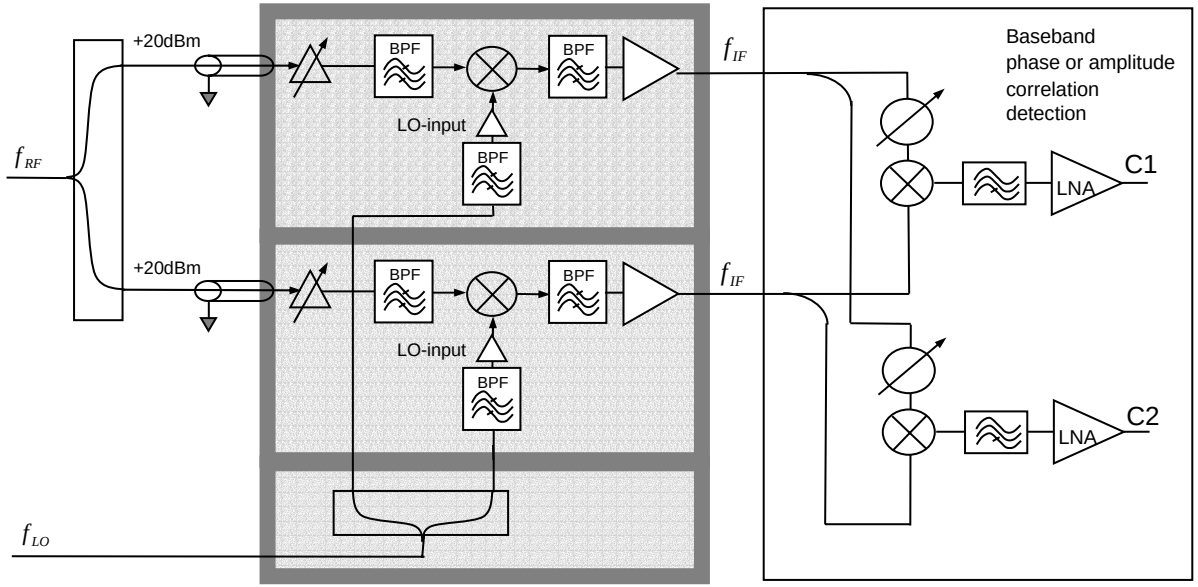
VME motherboard
for IQ detection



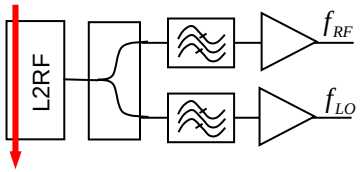
FPGA (IQ-detection, linearization, lookup tables)

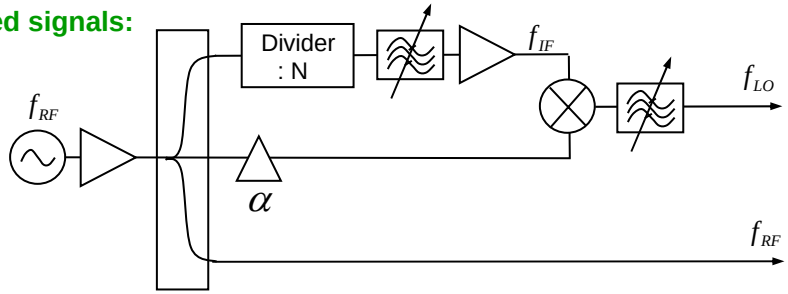
Test setup for the down-converter characterization

- **DWC analog frontend correlation test setup with fs resolution :**



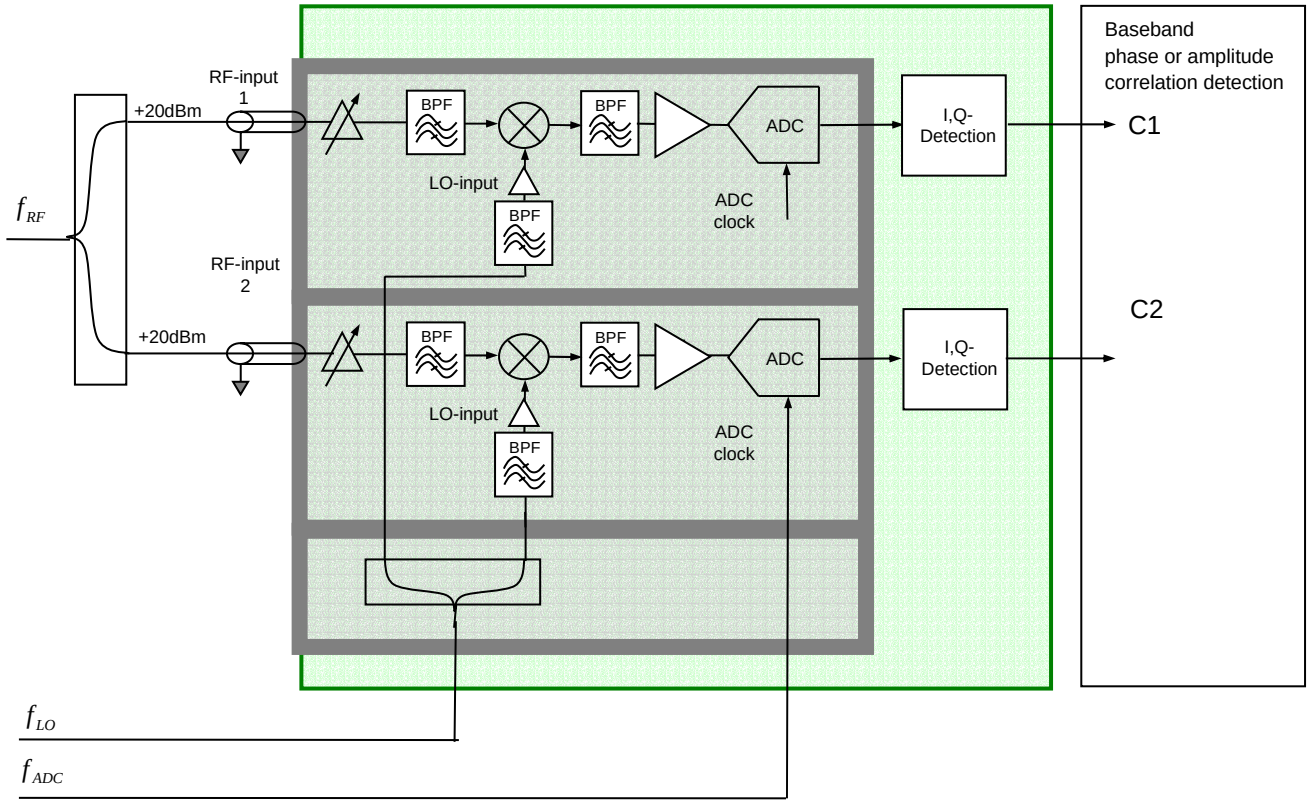
- **Reference system using nearly correlated signals:**





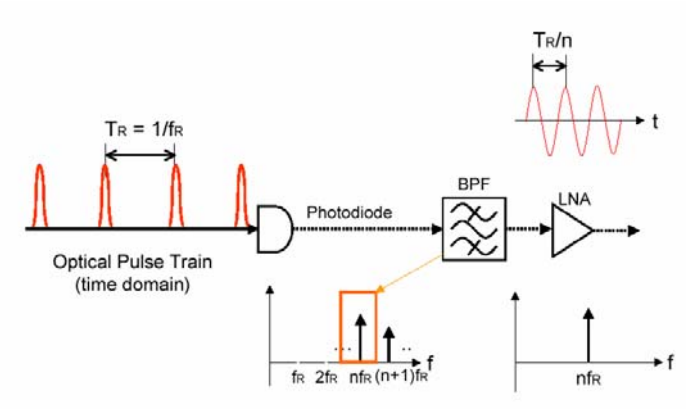
Test setup for the down-converter characterization

- **Complete DWC correlation test setup with fs resolution :**



Direct photodiode detection, injection locking

- **Direct extraction to RF from a pulse train :**



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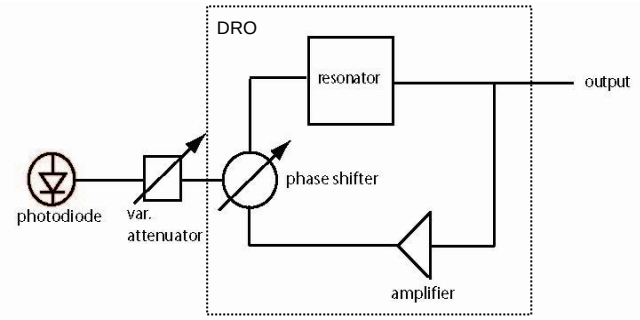
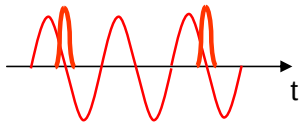
- 10fs(rms) jitter [1kHz-10MHz] @ 1.3GHz is achieved.
- Typical AM to PM conversion 1-10ps/mW.

- **Injection locking :**



- Locked state at zero crossing

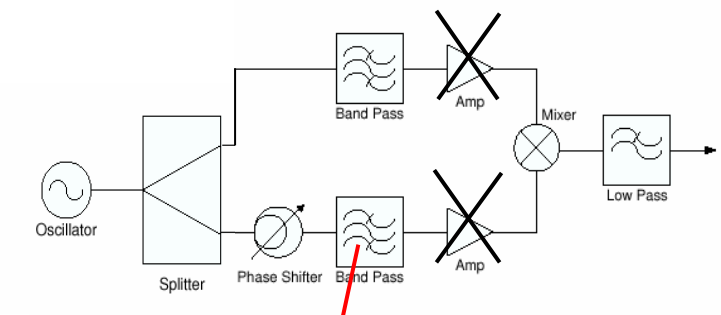


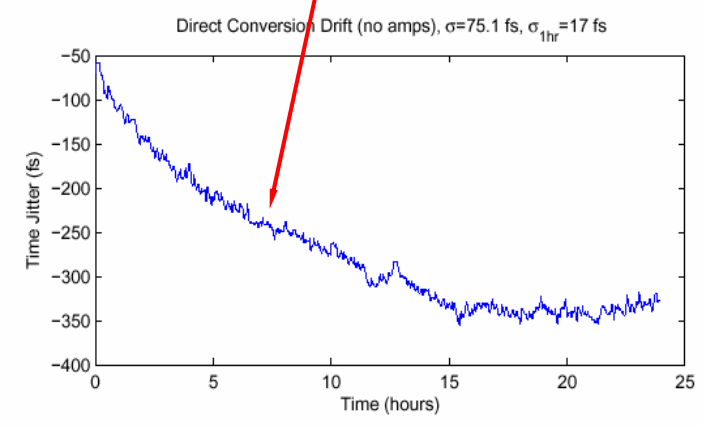
- DRO changes center frequency with ist VCO input.
- DRO follows laser phase noise for lower offset frequencies and is free running for higher frequencies.

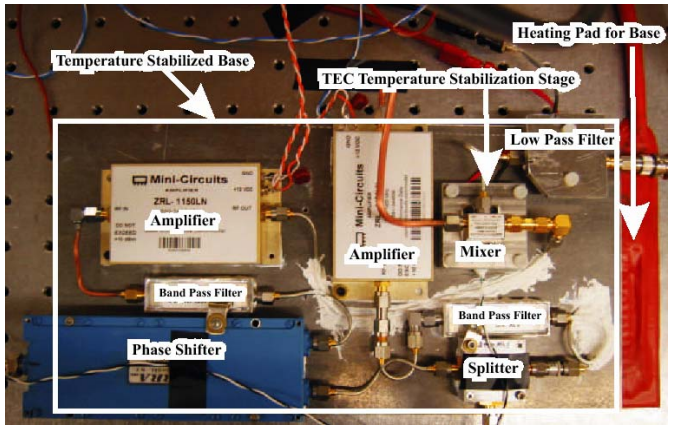
- Conversion from optical to RF is a major bottleneck concerning noise, stability and power.
- Measure residual noise by beating two of them together.

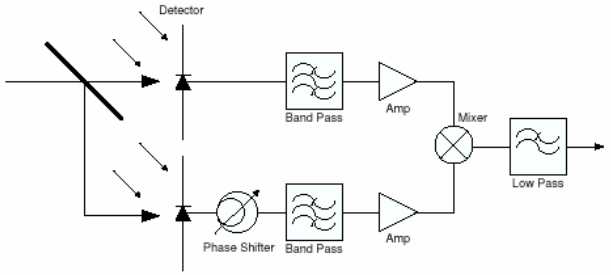
FLS Workshop, DESY 2006: A.Winter et.al. „Recent Developments and Layout of the MO System at the VuV-FEL“.

Direct photodiode detection – long term phase drifts





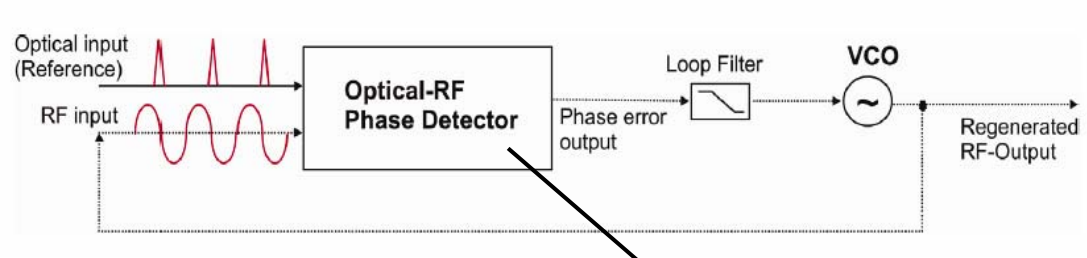




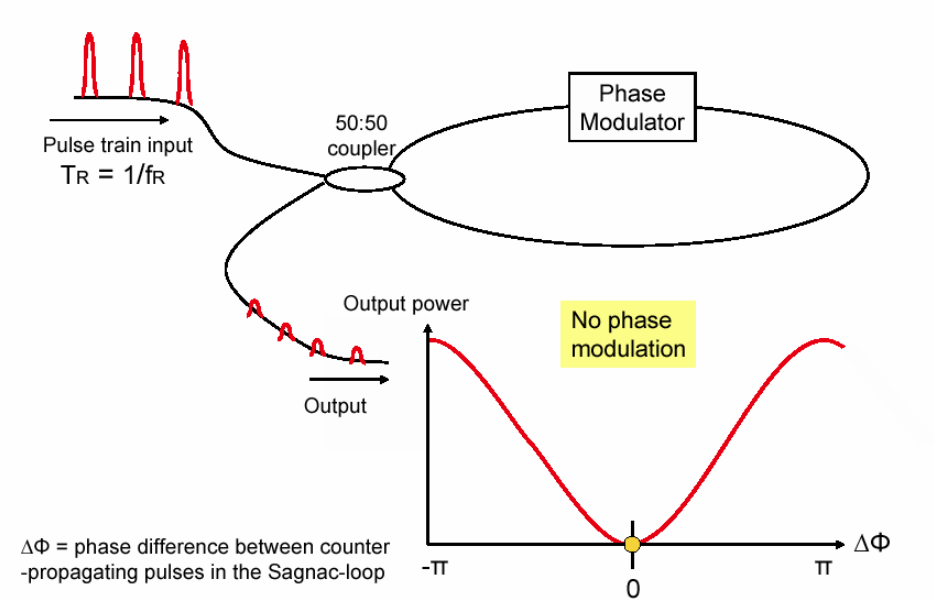
- Mixer drifts with approx. 20fs(rms) / 6hr.
- Bandpass filters seems to be drifting!

- Calibration or zeroing the phase during the pulse pause against an rf-reference from MO ?
- Self-Calibration against virtual reference (compare Agilent SSA) possible ?

- **Phase-locked loop (PLL) :**



- **Optical to RF phase detector :**
  (Sagnac-loop)



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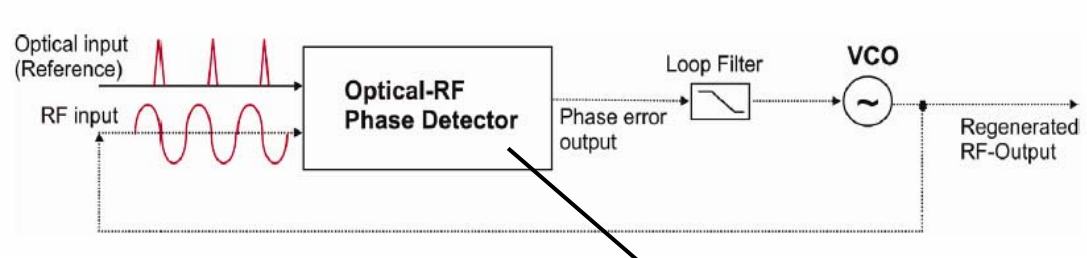

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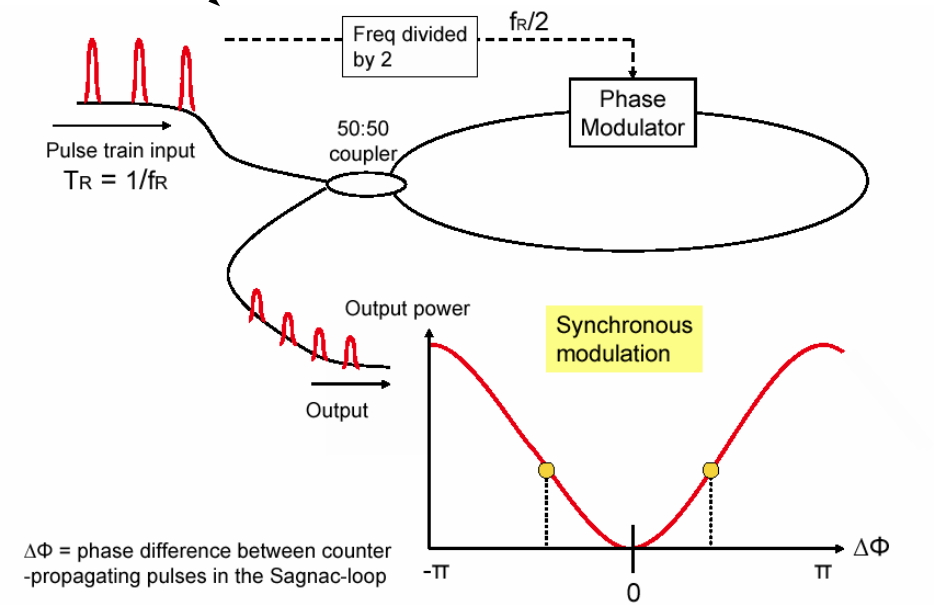

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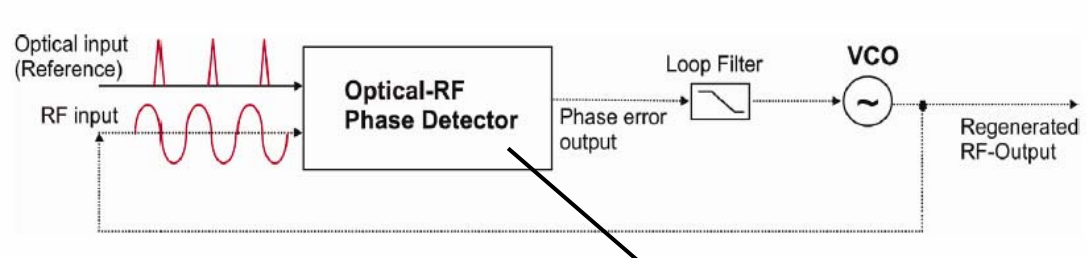

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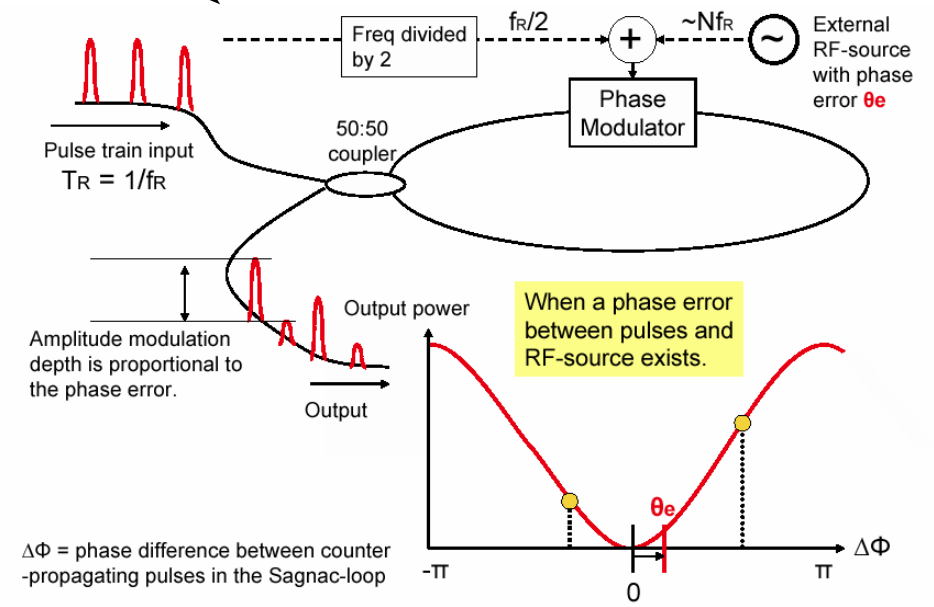

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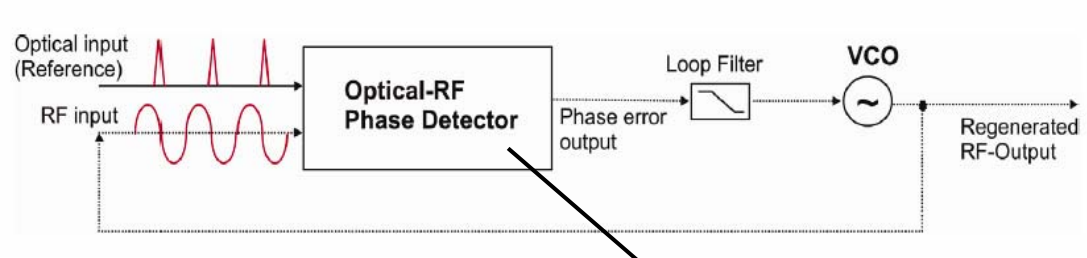

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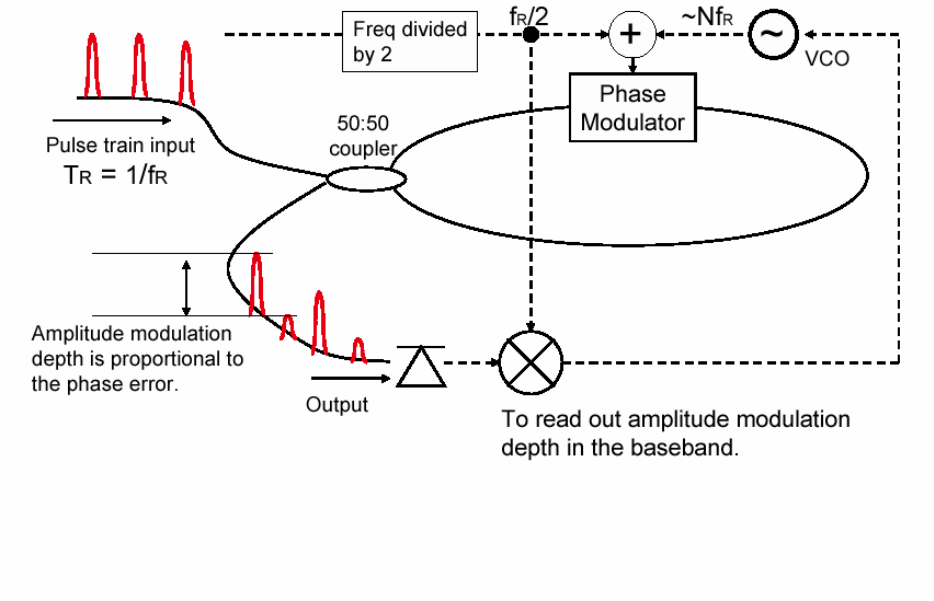

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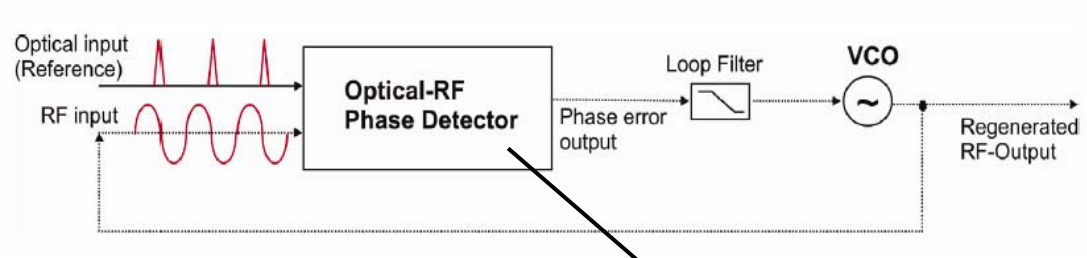

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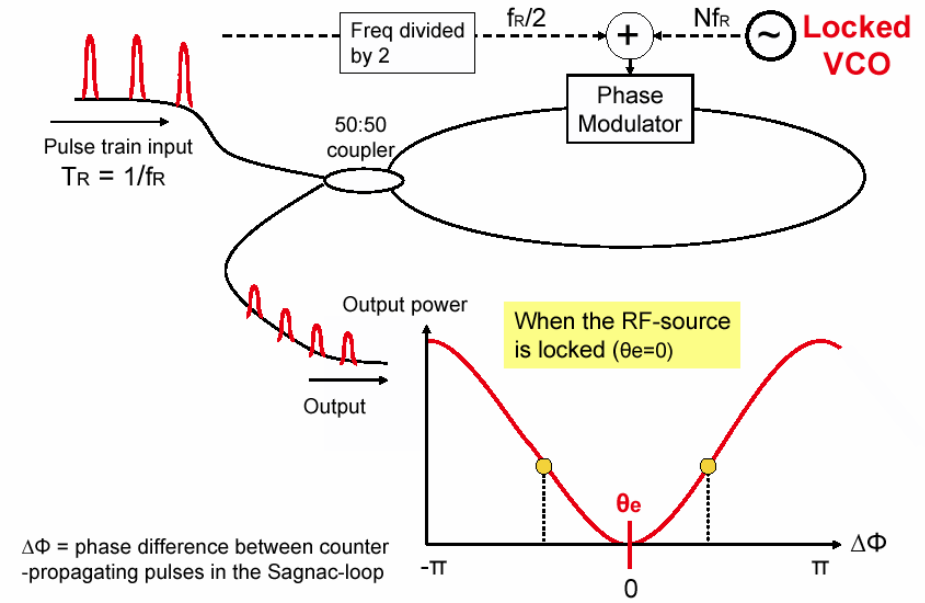
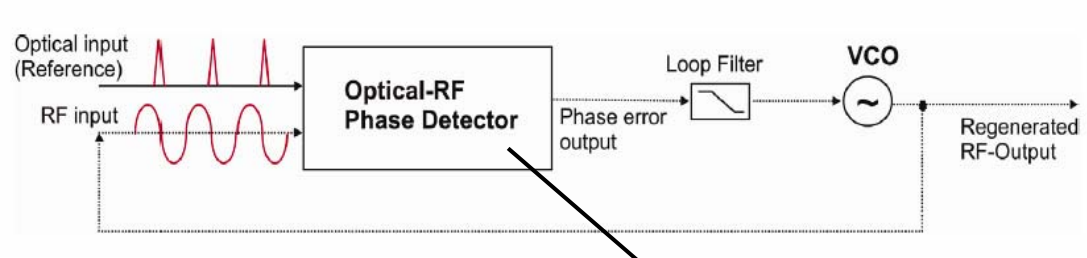
  (Sagnac-loop)



- **Phase-locked loop (PLL) :**



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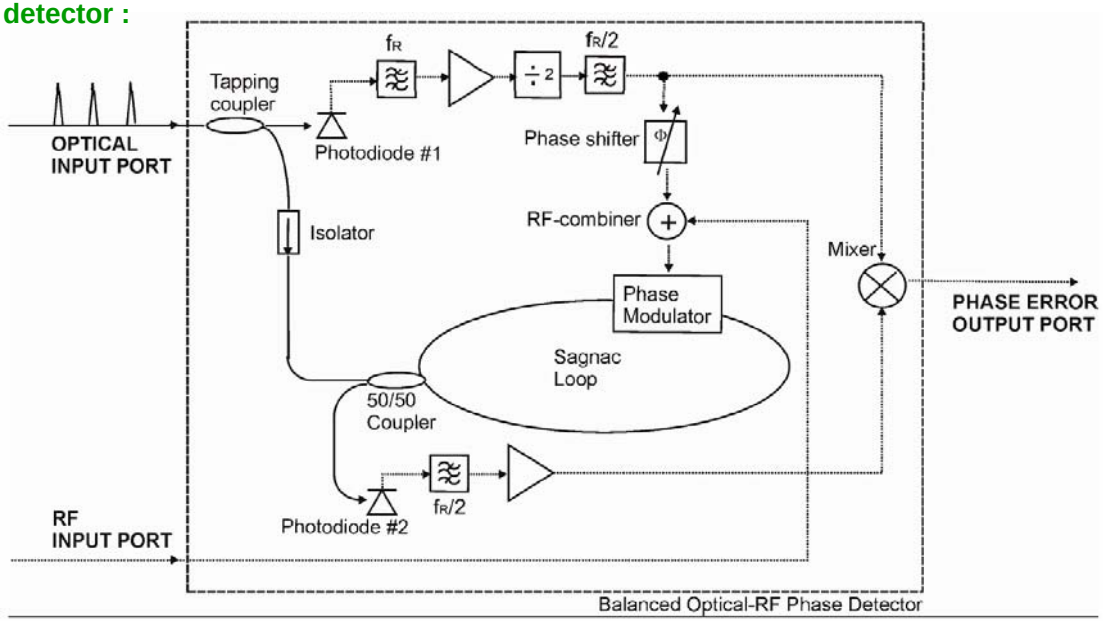
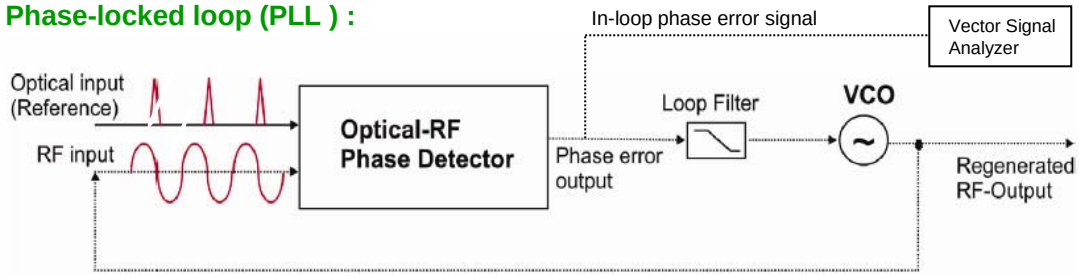
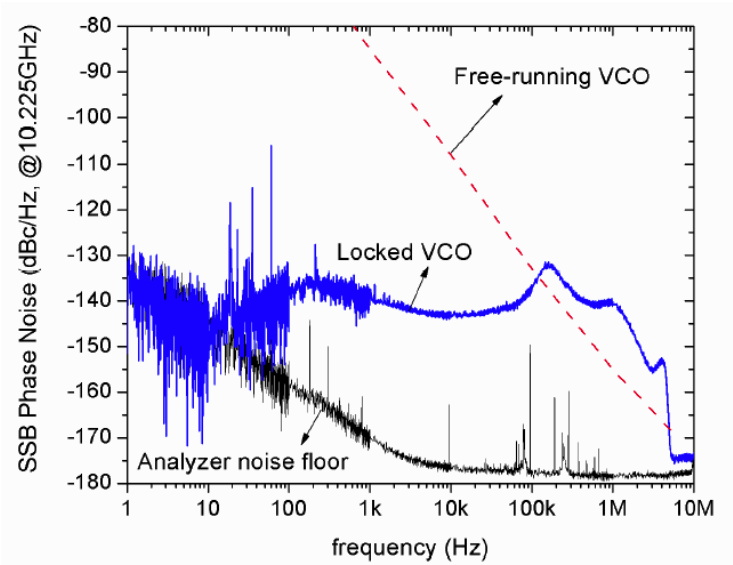


Optical to RF conversion – sagnac loop

- **Phase-locked loop (PLL) :**



- **In-loop phase noise measurement @ 10.225GHz :**



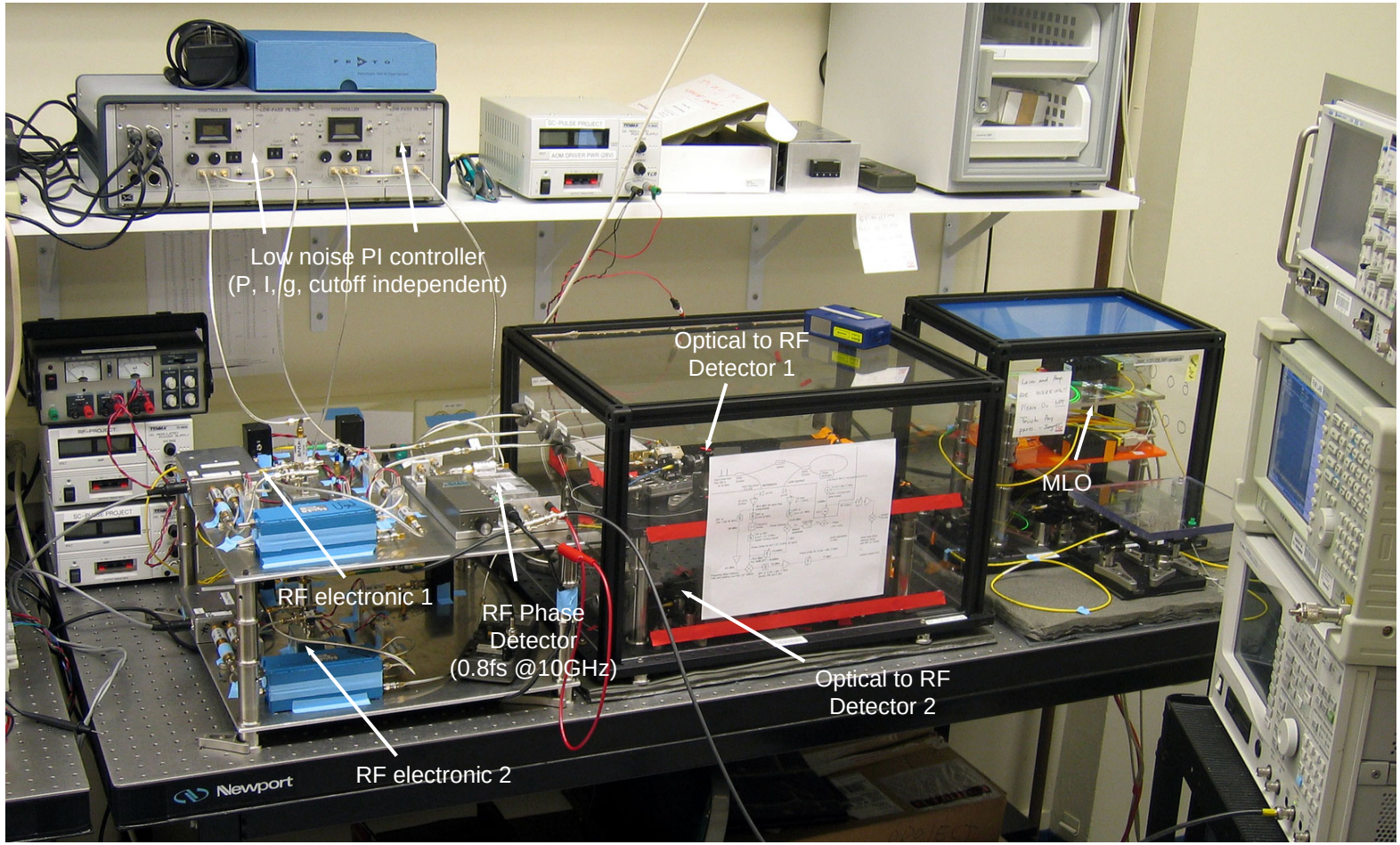
- Residual in-loop jitter <10fs [1Hz-10MHz].
- High-power VCO's -> High-power signals.
- Scalable phase detection sensitivity -> low jitter.

$$K_d = \frac{V_d}{\Theta_e} \propto P_{avg} \Phi_0 \Phi_m$$

- Fiber based balanced scheme -> low drift.

- Direct measurement of two L2RF converter using an RF phase detector with 0.8fs @ 10GHz.
- Investigate influence of electronic noise...

Optical to RF conversion – sagnac loop



Summary and Questions

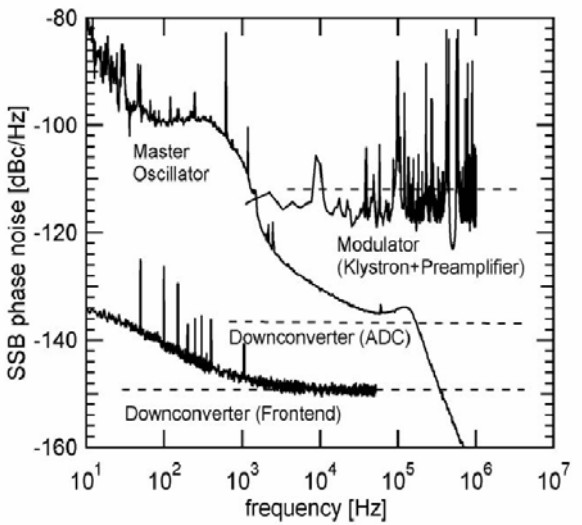
- **to do list :**
  - *Design diplexer for frontend mixers.*
  - *Setup and test calibration hardware.*
  - *Test setup for the down-converter characterization.*
  - *Planned Multichannel versions (4 designs)*
    - *Frontend versions: Gilbert mixers, passive and high level mixers*
    - *Multichannel packaging: Frontend incl. ADC's, Frontend excl. ADC's, SMD Multilayer low cost version*

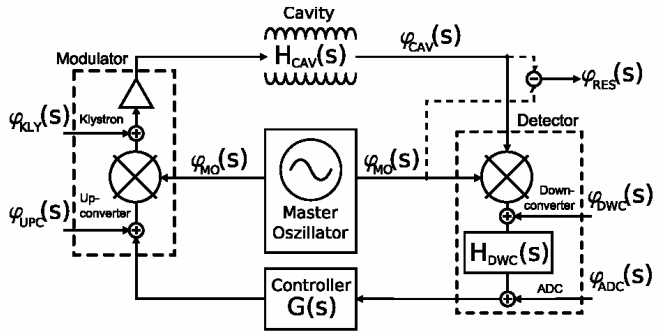
  - *Test setup with fs-resolution for beating two optical to rf converters.*
  - *Improve direct photodiode detection, injection locking and the sagnac loop.*
  - *Drift characterization, amplitude and phase noise description.*

Thanks for your attention!

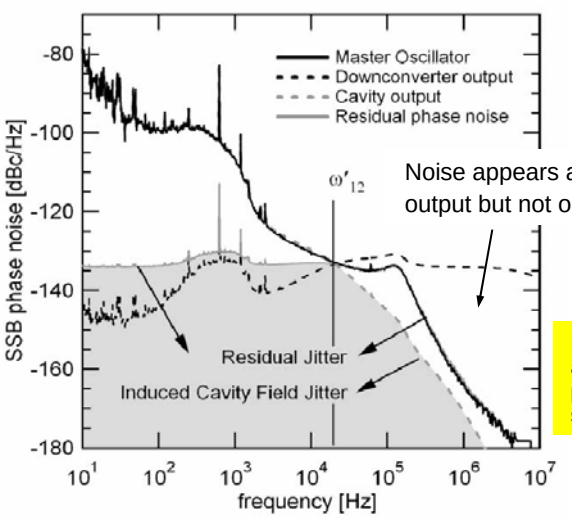
Phase noise budget at FLASH (Switched LO, single cavity)

- **Phase noise measurements :**





- **Contributions to cavity field jitter :**



Noise appears at the DWC output but not on the cavity field!

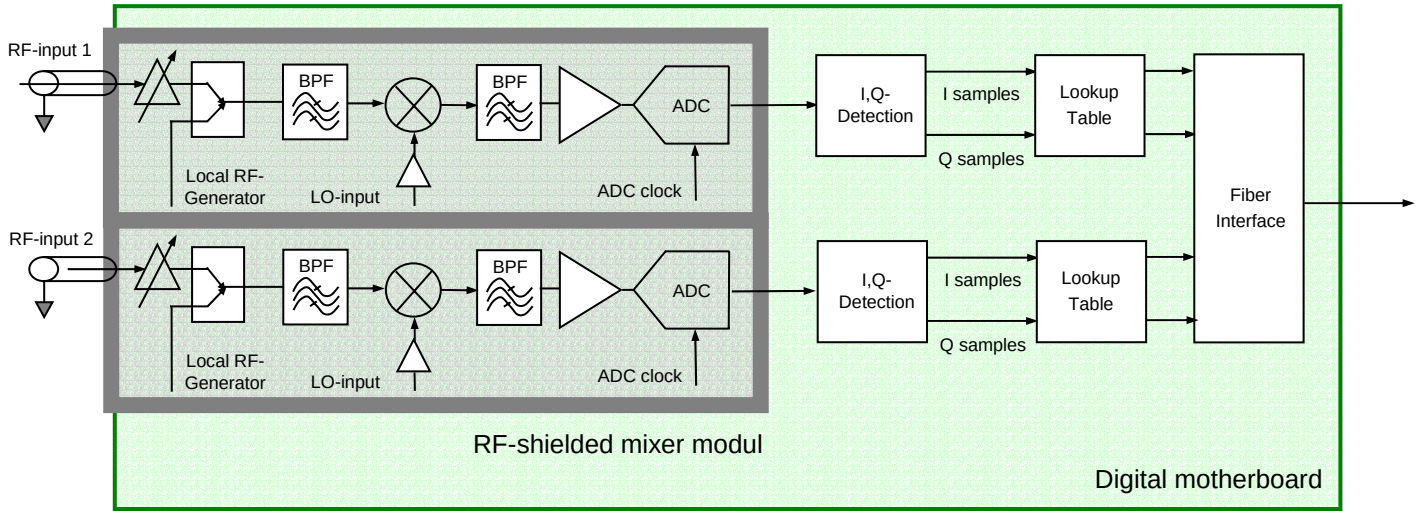
EPAC06: F.Löhl, et. al. „fs-fiberbased phase monitor with sub 100fs resoultion“.

Subsystem	Phase noise [dBc/Hz]	Residual jitter [fs]	Induced jitter [fs]
MO	see Fig.3	14.1	5.5
DWC (Frontend)	−147	1.8	1.8
DWC (ADC)	−135	5.8	5.8
MOD	−110	1.2	1.2

- High frequency noise is filtered by the cavity, but not drifts!

Hardware calibration of the down-converter in amplitude and phase using a local rf-reference.

- **Multichannel down-converter block diagram :**



Digital motherboard:

- provides timing signals for linearization within the beam pause
- FPGA (IQ-detection, linearization, lookup tables), Fiber interface

RF-shielded mixer modul :

- Attenuators, mixer stage and ADC with strong connection of its AGND to RF GND.
- SMD connection of digital ADC signals to digital motherboard.
- Different mixer or ADC types can be used by simply changing the frontend modul.
- For low crosstalk each channel is located within an rf-shielded subsection.