# WP 12.3: front ends for wake field monitors

M. Leich, M. Dehler

PSI

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- Signal to Noise ratio after detection in an analog optical system
- SNR :Test system
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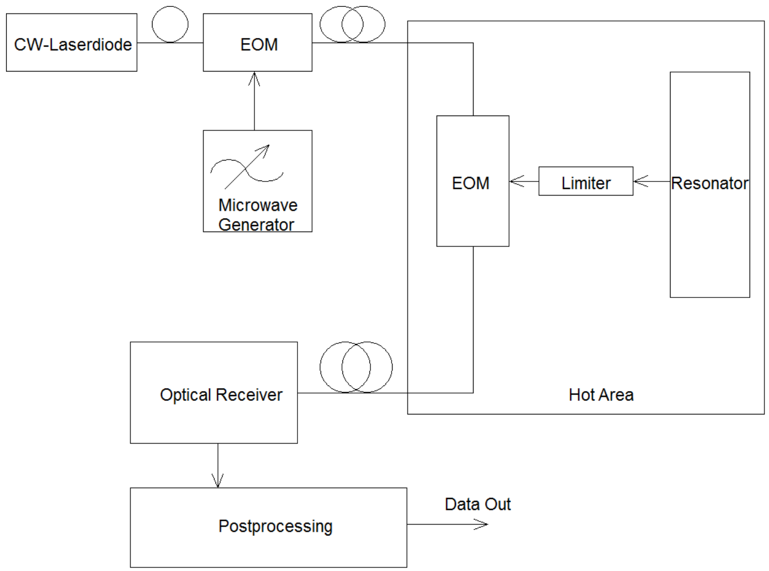
# Introduction

Evaluating Electro-Optical: Modulate CW optical signal with a first EOM with a LO, then with another EOM with WFM signal, convert to electrical signal with mixing signals in photo diode:

- Technology already used in space communications
- Optical fibers vs. hollow wave guides, coaxial cables and microwave mixers in classical RF
- 'Passive' front end (essentially only optical modulator) near structure: robust to radiation damage
- Off the shelf components available up to 40 GHz: possible secondary applications for break down monitors, wide band wall current pickups etc.)

# Front end: basic optical concept

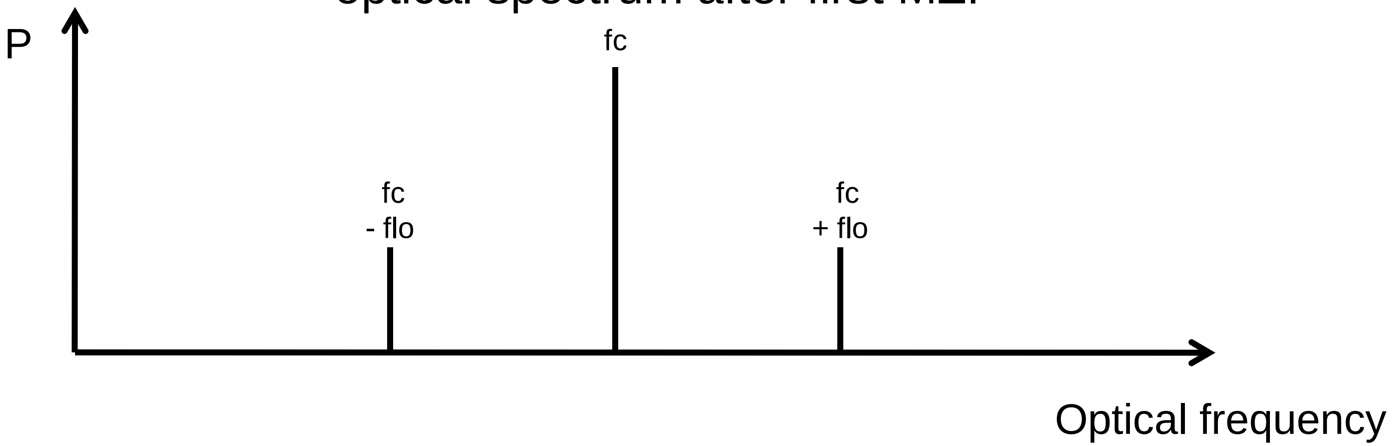



- CW optical signal from laser diode gets modulated with local oscillator at 12-15 GHz
- 2nd modulation of optical carrier by WFM signals via MZI type electro optical modulator – WFM signals get optically up-/down converted by LO frequency
- Photo diode converts down converted WFM pulse back into electrical signal
- Not shown: analog electrical post processing, 2 paths:
  - Logarithmic amplifier (-60dBm sens., 70 dB dyn. range) to give 'operator signal'
  - Fast high sensitive tunnel diode detector (-80 dBm sensitivity, 1V/uW) for structure straightness

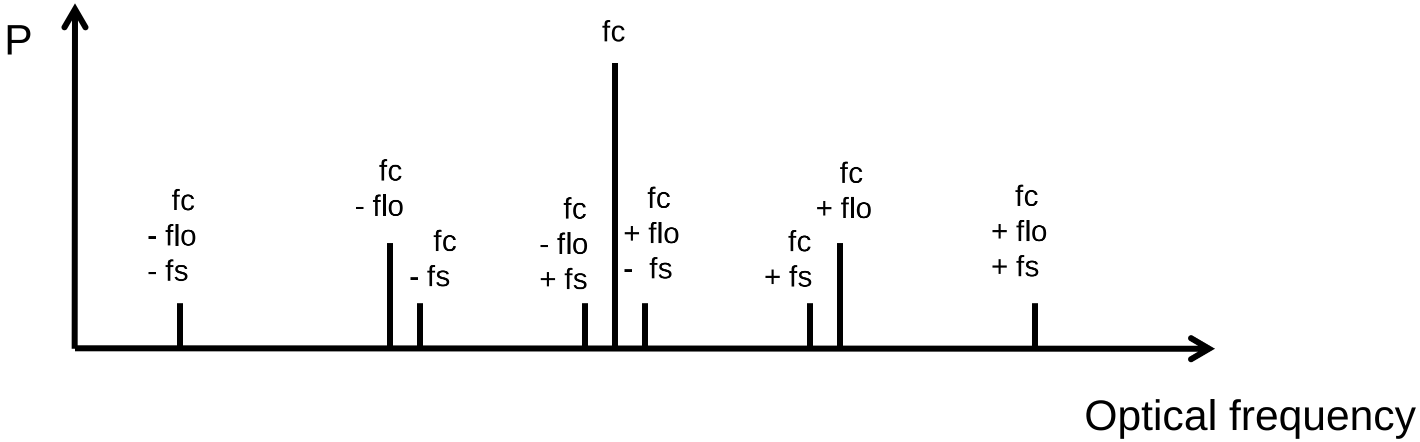
# Process of double modulation



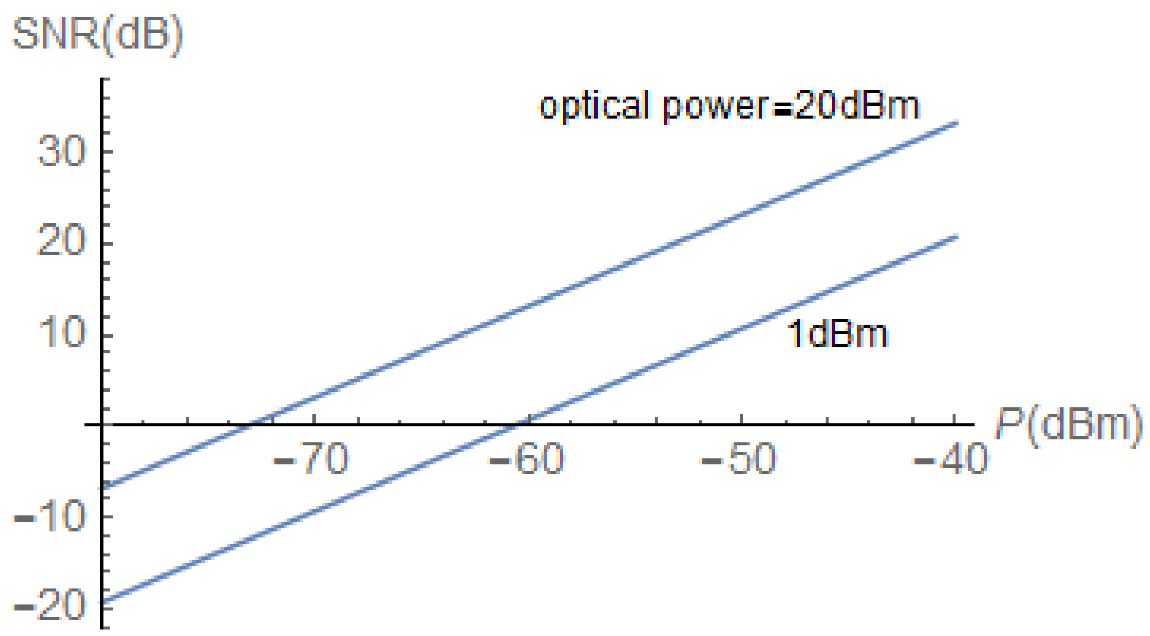
optical spectrum after first MZI




optical spectrum after second MZI

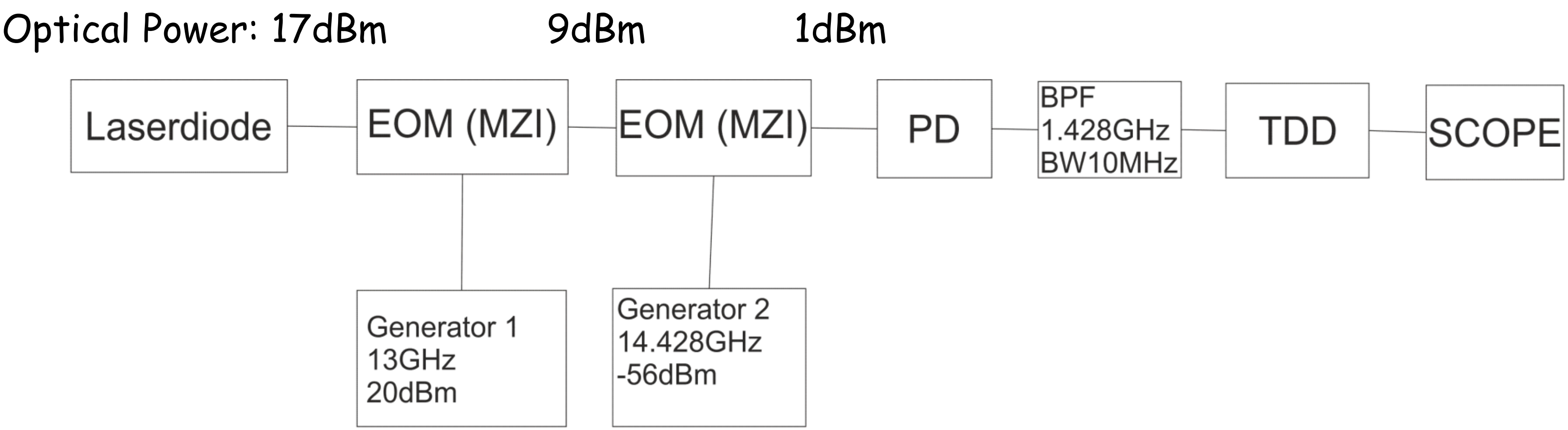


# Signal to Noise Ratio after detection in an analog optical system



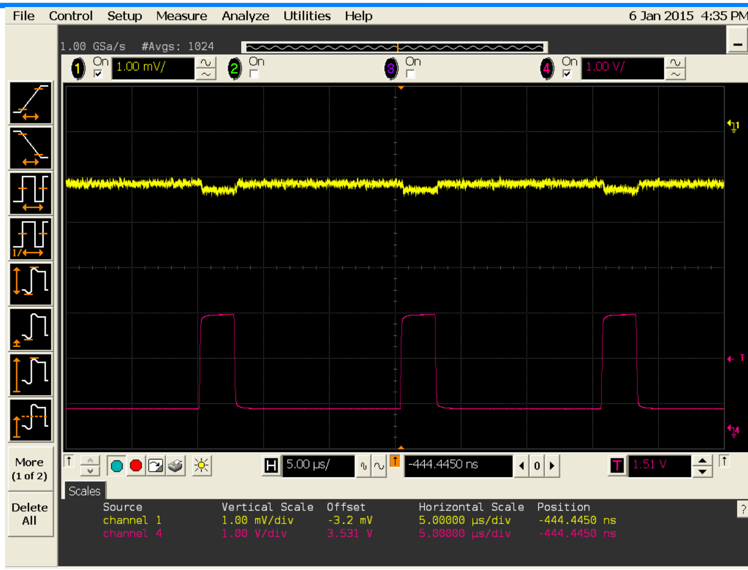

- Signal to Noise ratio after detection as a function of the power of a raw sinusoidal signal with the detected optical power as a parameter: shot noise as a significant additional noise source

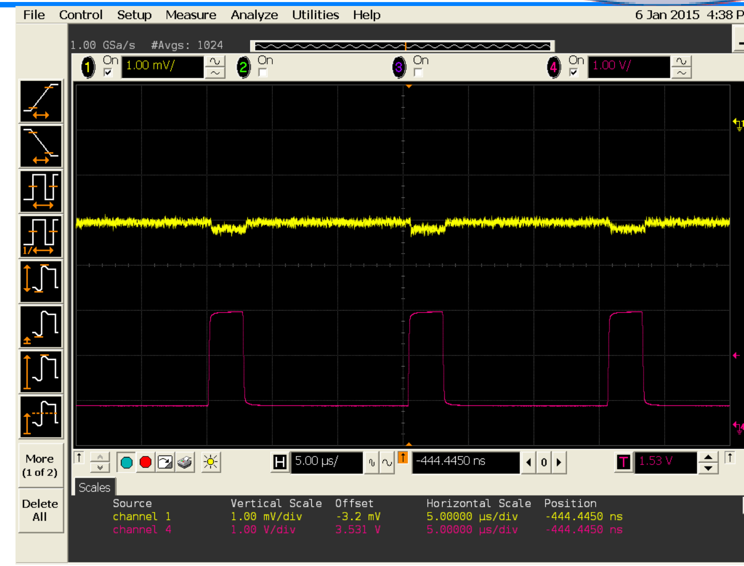
# SNR :Testsystem




- Experimental setup to test the system performance without access to accelerator

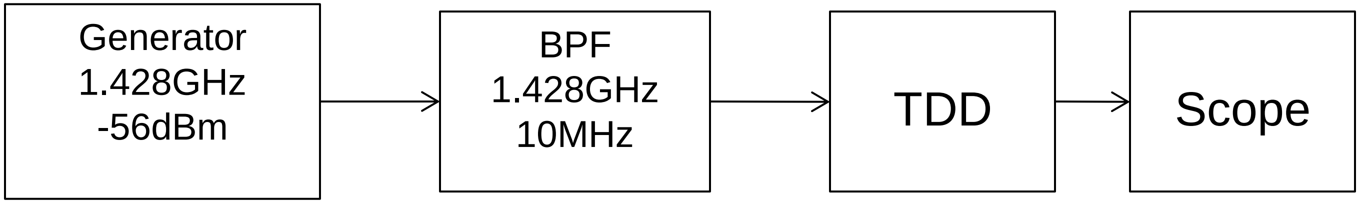
# SNR : Testsystem



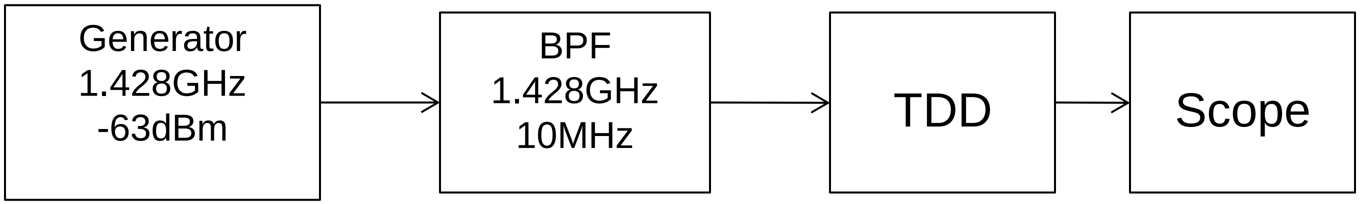

- Signal of a emulated pulse in the test system with tunnel diode detektor and 10MHz band pass filter. Power level -56dBm. SNR is close to 0dB, an R&S spectrum analyzer FSEK30 performs with -75dbm/3MHz = -70dBm/10MHz.
- With cable losses included the penalty is around 11-14dB.
- Loss of the long cables is 25dB, loss of a frequency mixer is 7dB
- An equivalent system with best possible coaxial cables (0.6dB/m) would work with 6-11m long cables, **fiber loss** is **0.6dB/km**

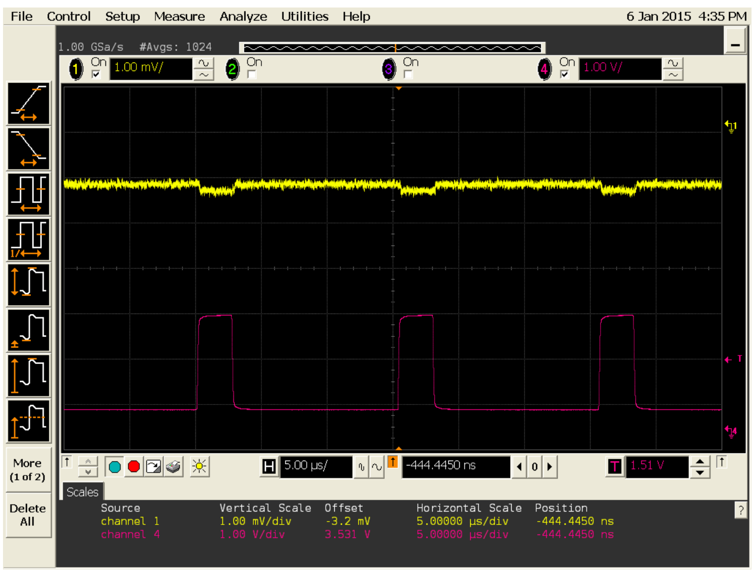
# SNR : Testsystem




# SNR : Testsystem

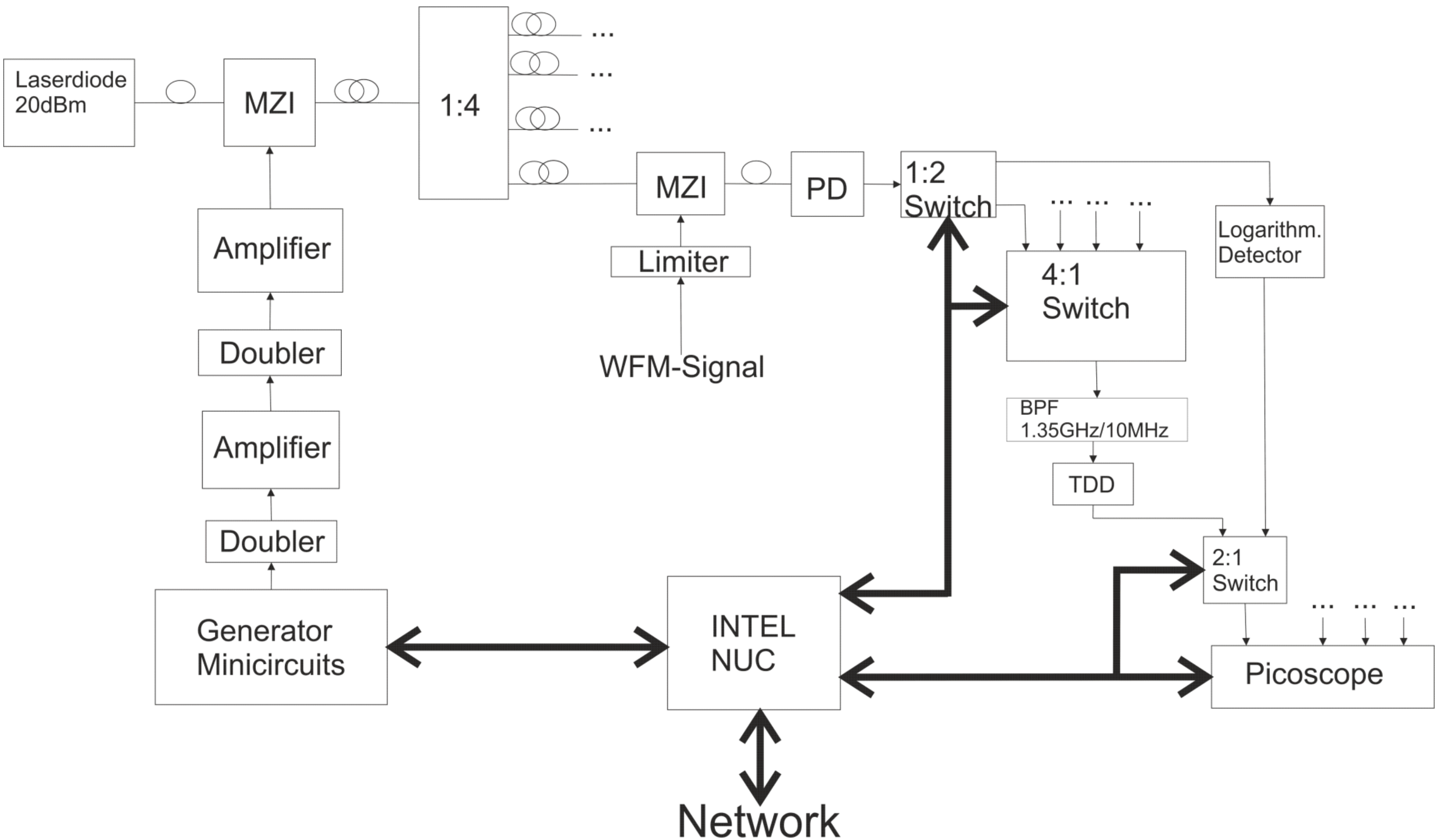





**Typical frequency mixer:**
ZX05-24MH+ (minicircuits)
Conversion loss: 7dB

# Block diagram of the system to be integrated



# Impressions of the system to be integrated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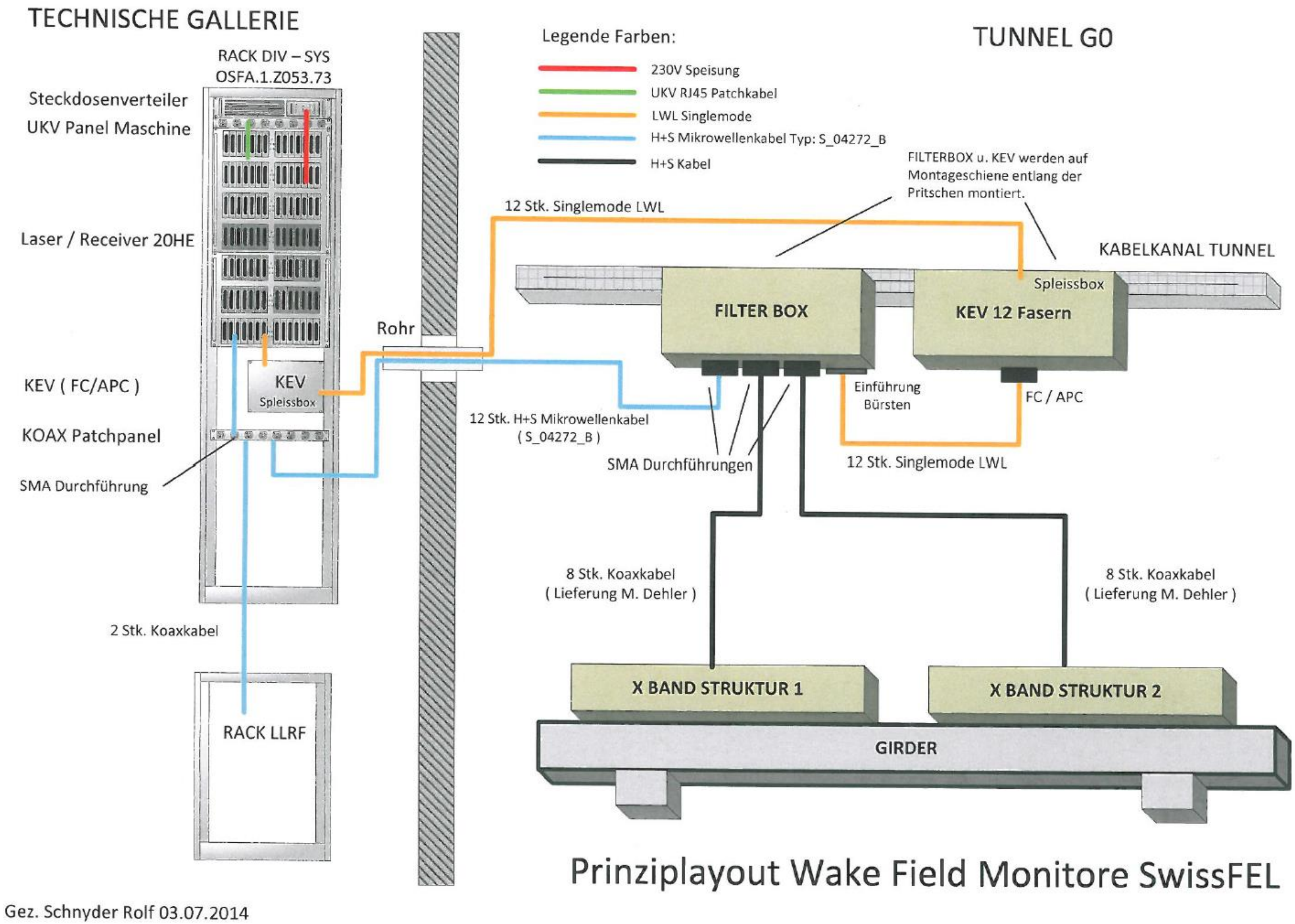
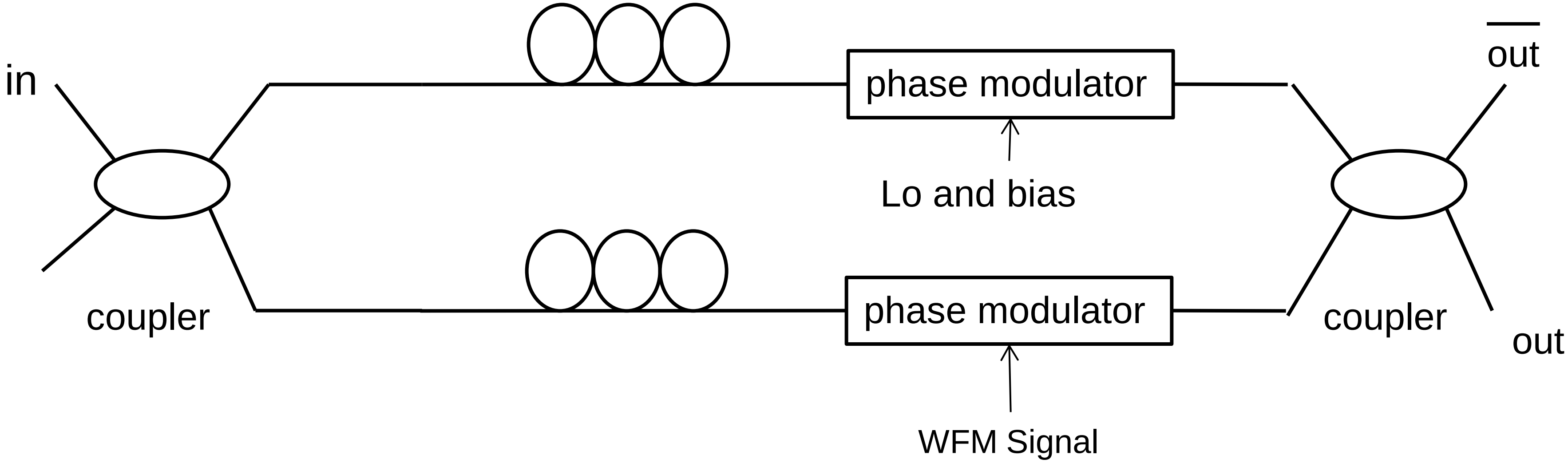


# Alternative Ideas



- Reducing shot noise: higher optical power level needed at detector
- Avoiding electrical lines to feed bias voltages into the tunnel
- Simpler structure of the system

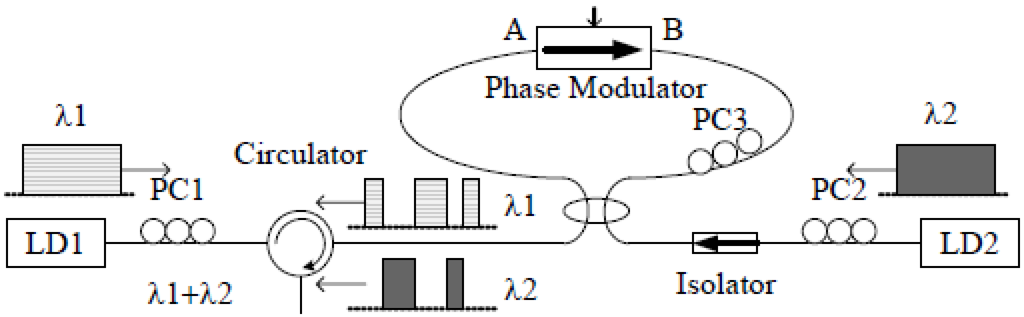
Single MZI with distributed phase modulators:



# Alternative Ideas

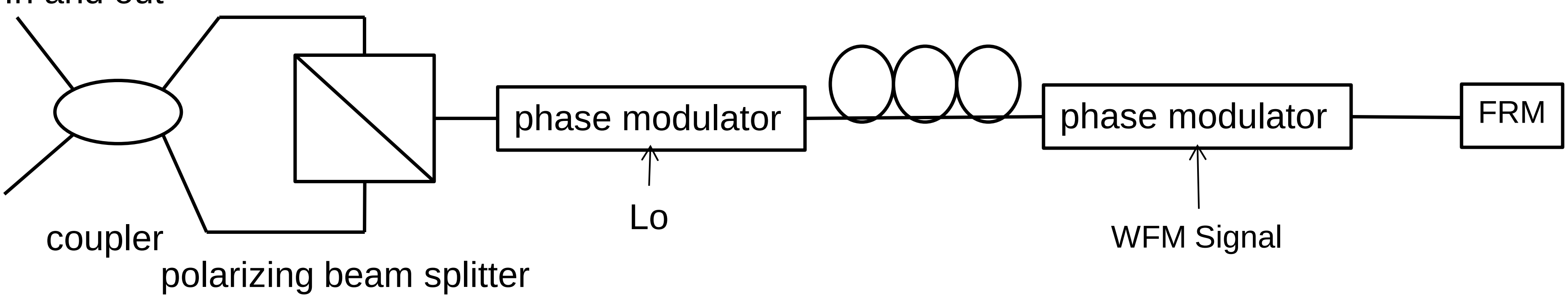


## Loop Mirror




[Zhaoxin Wang, Chun-Kit Chan , Chinlon Lin]

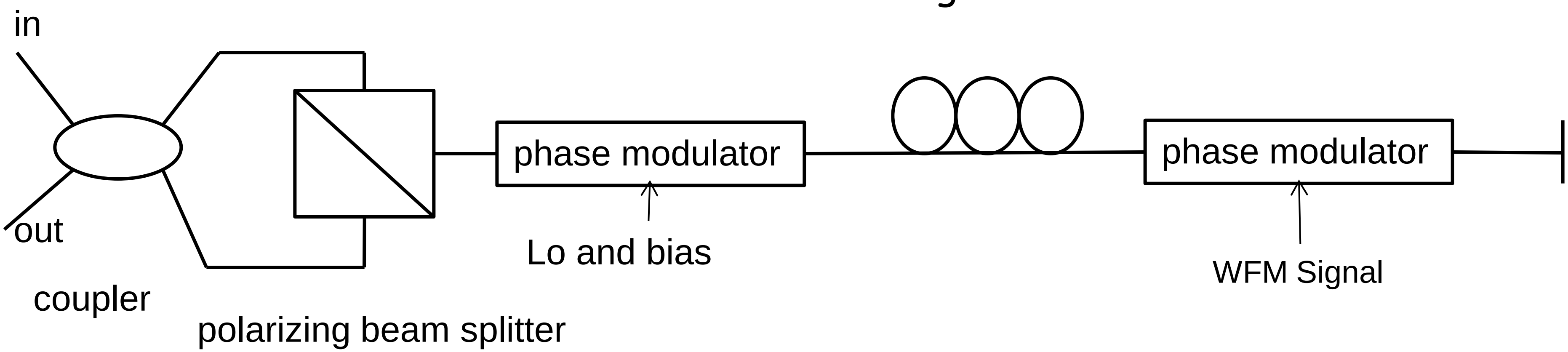
## Loop mirror in a single PM fiber:




-no tuning to linear operation possible, but harmonik mixing in the optical domain (with high conversion loss)

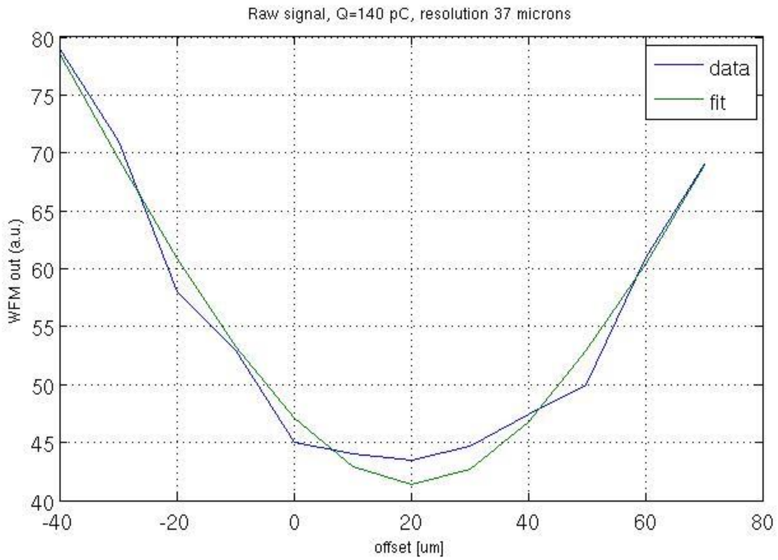
# Alternative Ideas

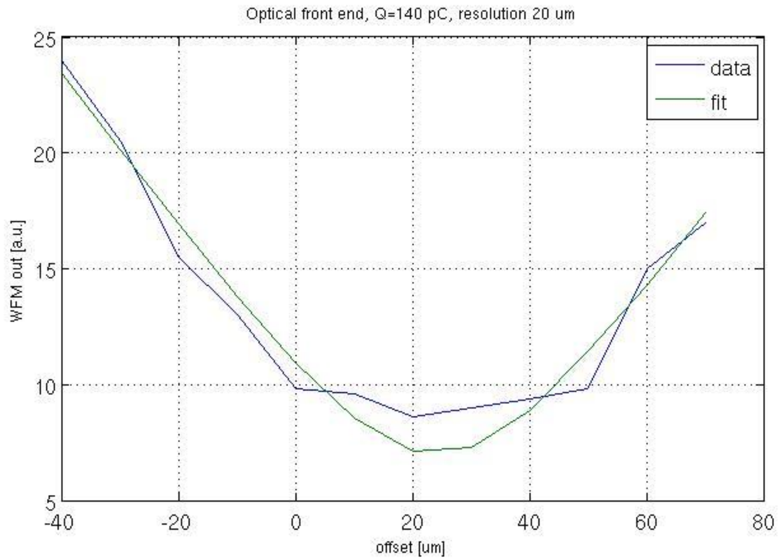
Michelson interferometer in a single PM fiber:




-Change in mechanical tensions or thermal fluctuations on the PM fiber will be compenmsated, but not due to the bend radii

# A very preliminary comparison of system performance




Comparison of system resolution, bunch charge 140 pC (nominal would be 200 pC)

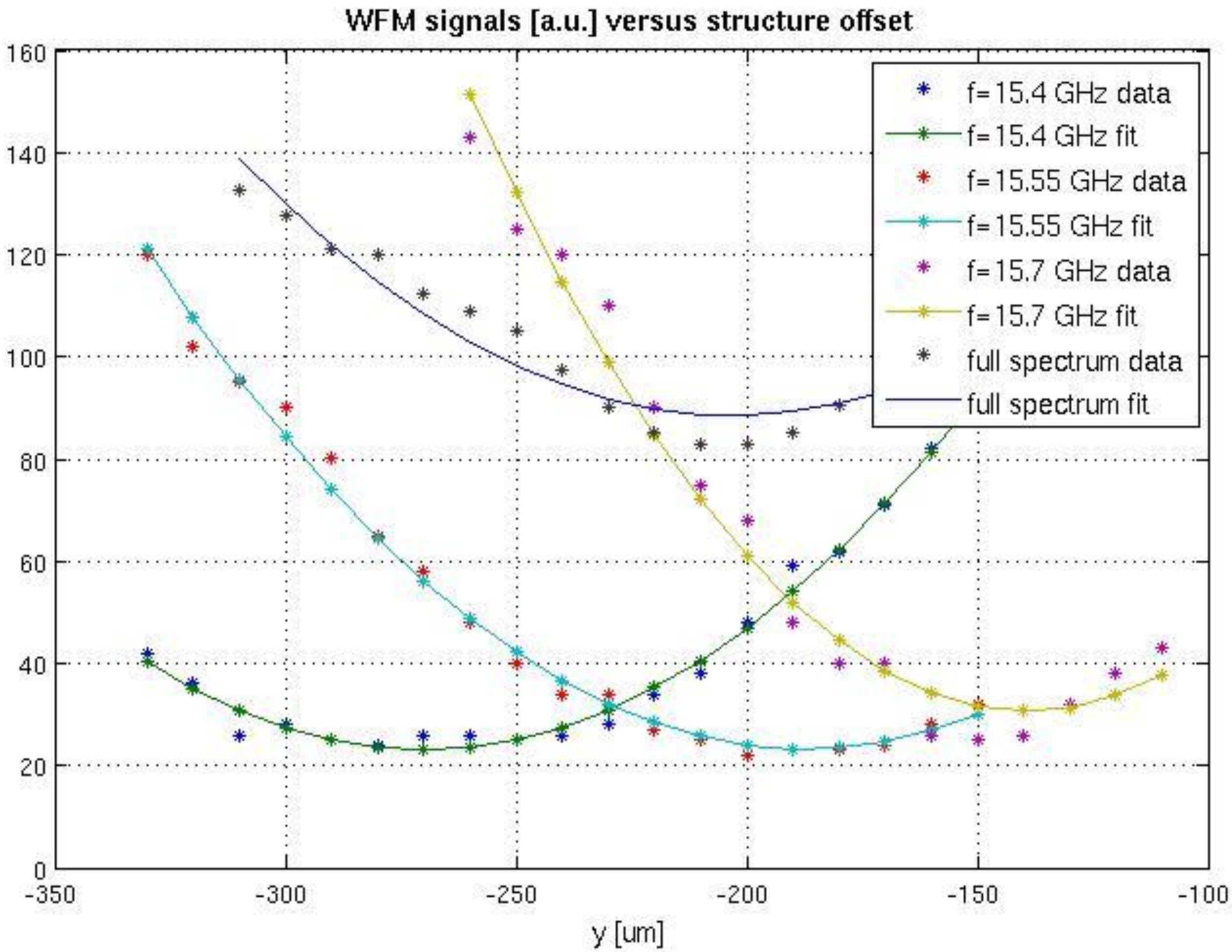
•Read out of raw signals via high speed scope, nominal 8 bit, ENOB ~ 6.5 bit, gives a resolution of 37 µm

•Optical front end (Laser/EOM/PD), read out via scope with electronic band width limitation resulting in resolution enhancement (ENOB ~ 9 bit), gives resolution of 20 µm

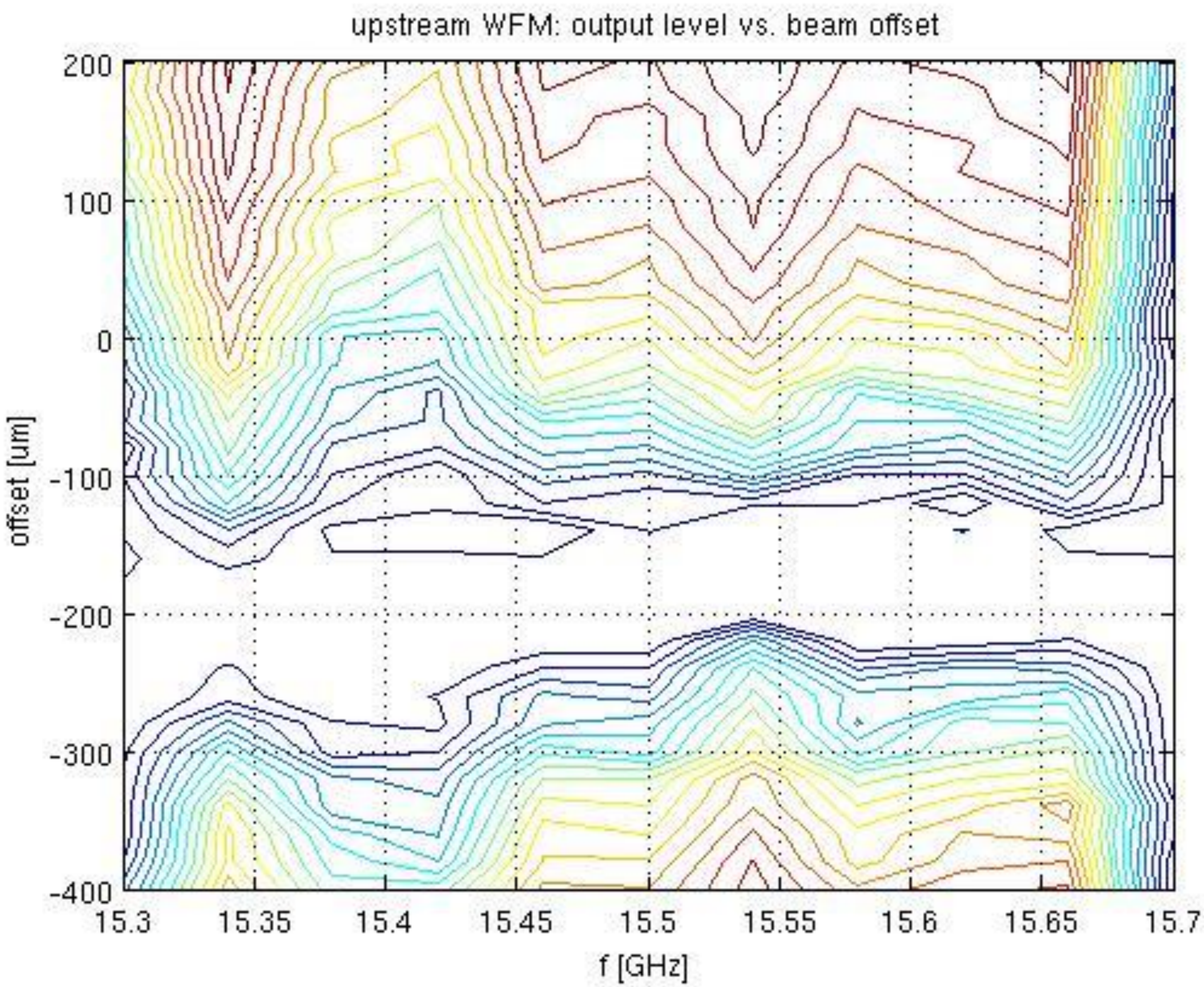
•Results deteriorated by bunch to bunch charge jitter and drift and mechanical hysteresis effects

**BUT – important: scaled to 200 pC, EOM resolution of ~ 14 µm**

# Last measurements in WHLA



# Last measurements in WHLA



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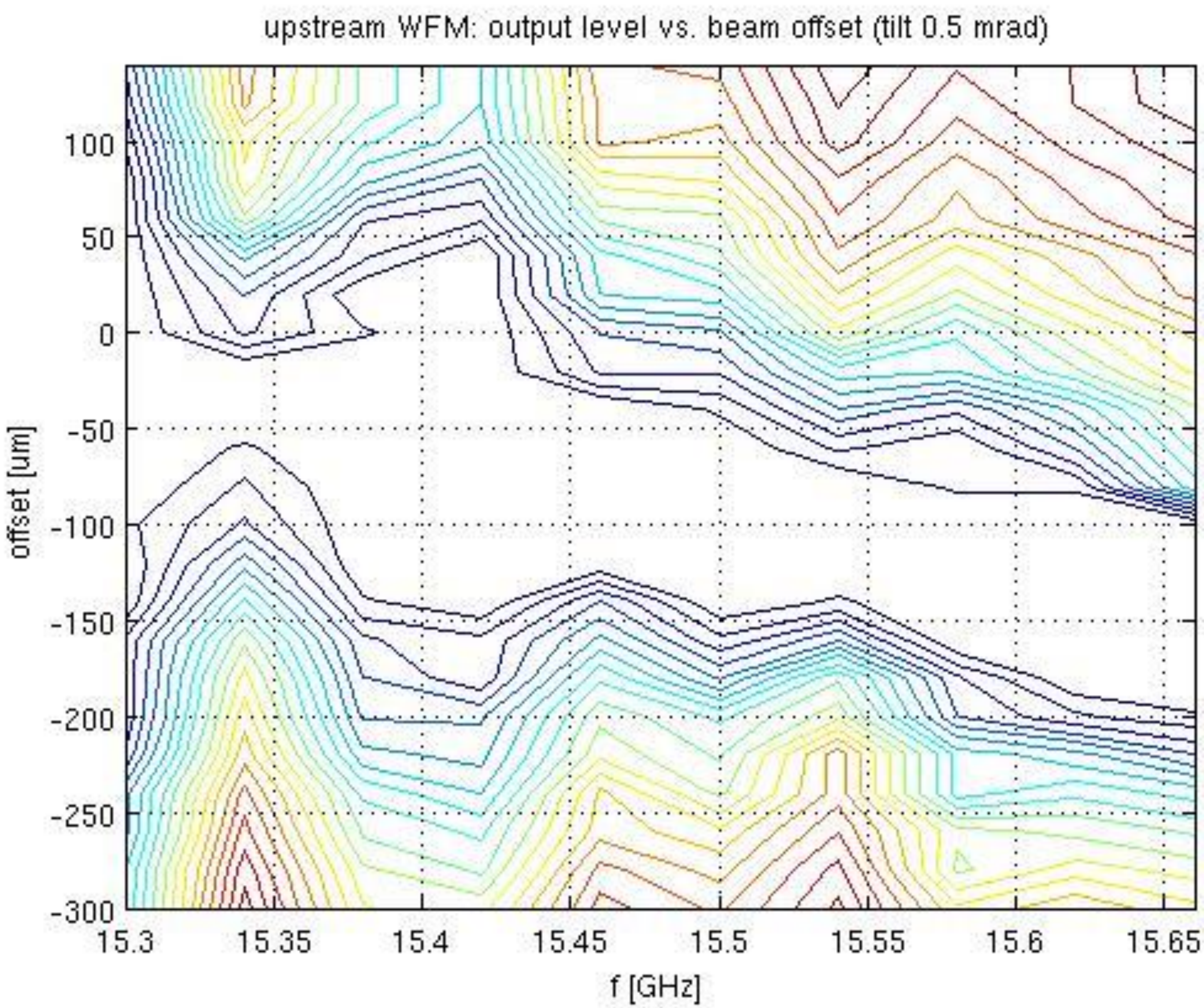

# Conclusion and Outlook

**State of things**

- Noise behavior comparable to standard electrical system with short coaxial cables, no degradation up to fiber lengths of several km
- Optical heterodyne detection emulated in time domain
- Preliminary design of the system performed, including the assessment and acquisition of the components needed
- Larger part of the system installed in 19inch rack
- Assessment of alternative structures in the optical part of the front end: single fiber based MZI, Fiber Loop Mirror, Michelson Interferometer
- Possibly tests at CALIFES