Sub-Kelvin cryogenics and Frequency-domain Readout for MKIDs

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The 4K base cooler

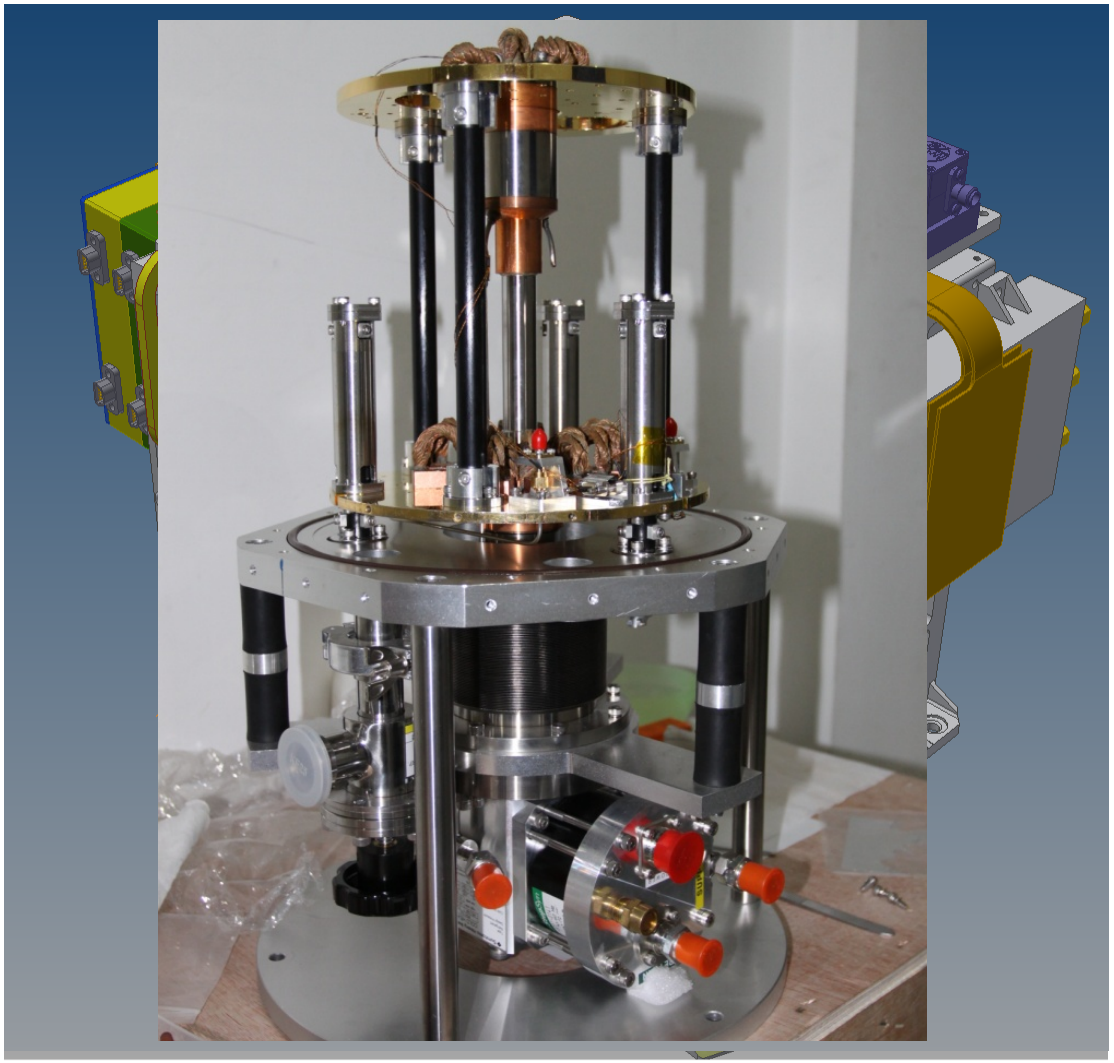
- Stirling + J-T
  - ✓ High efficiency
  - ✓ Small volume
  - – expensive
- GM
  - ✓ Simple & Cheap
  - ✓ High cooling power
  - – Vibration
- Pulse Tube
  - ✓ Reliable
  - ✓ Less vibration
  - – Orientation dependent

Sub-Kelvin Cryogenic Cooler

- He3/He4 Sorption cooler
- Adiabatic Demagnetization Refrigerator (ADR)
- Dilution Cooler

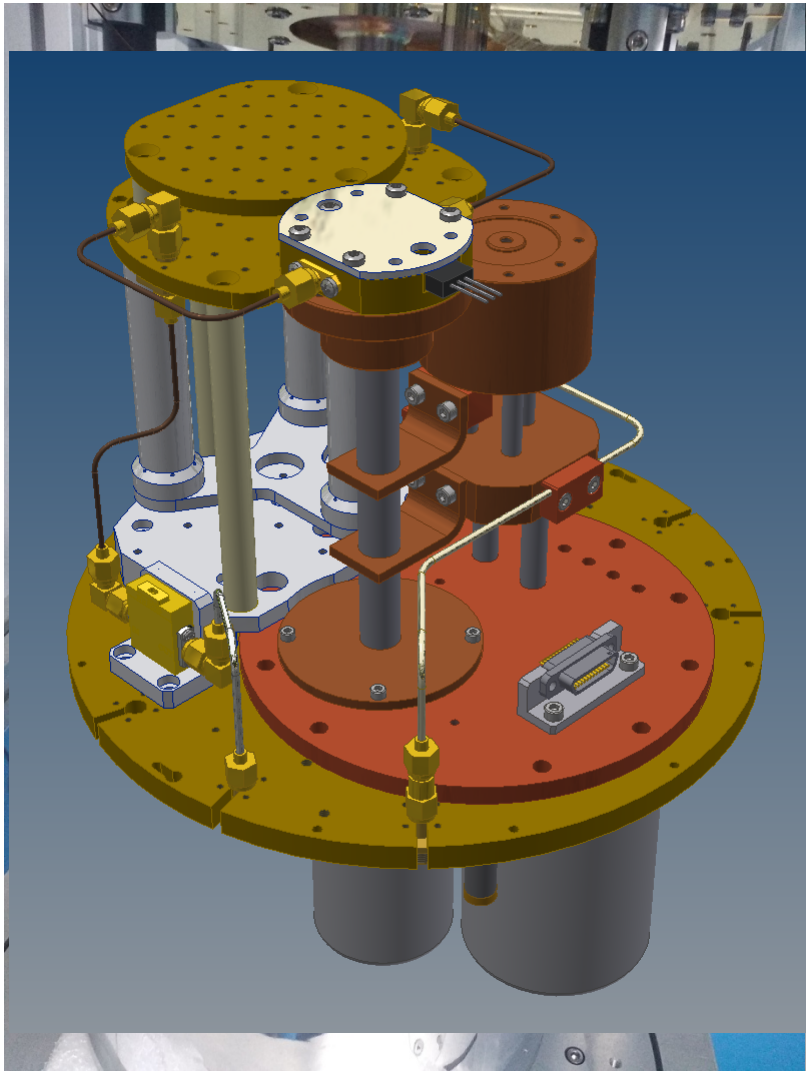
4K cryostat

- NbN SIS receiver for space
  - 8K high frequency PT
  - Launch reenforcement support
- Nb SIS receiver for Atmosphere
  - 4K compact GM
  - Vibration free



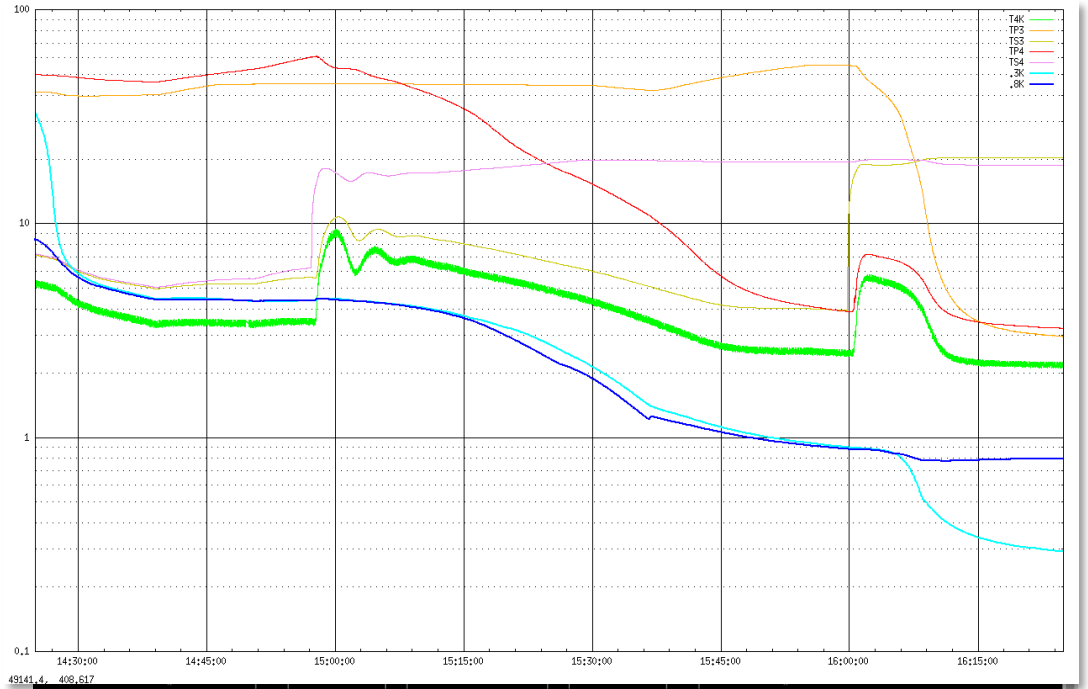
300mK sorption cooler platform

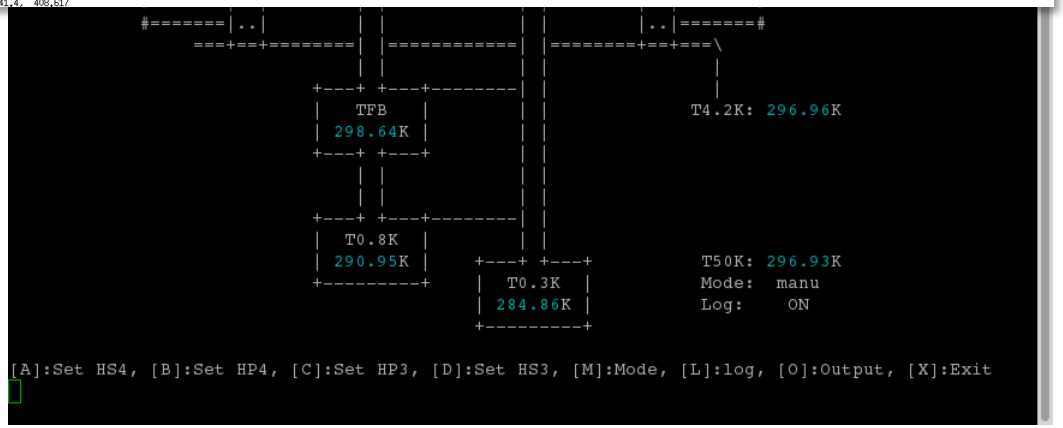
- CryoMech PT407 4K base platform
- Chase Cryogenic Research He7 sorption cooler
- Compact assembling
- Careful wiring and heat sinking



Sorption cooler cycling

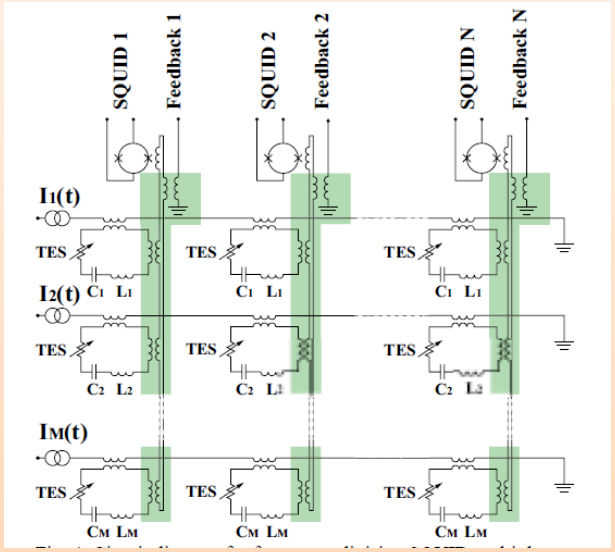
- LS350 + LS218 for heating and sensors reading
- Visualized text UI under Linux
- Manual & Automatic cycling





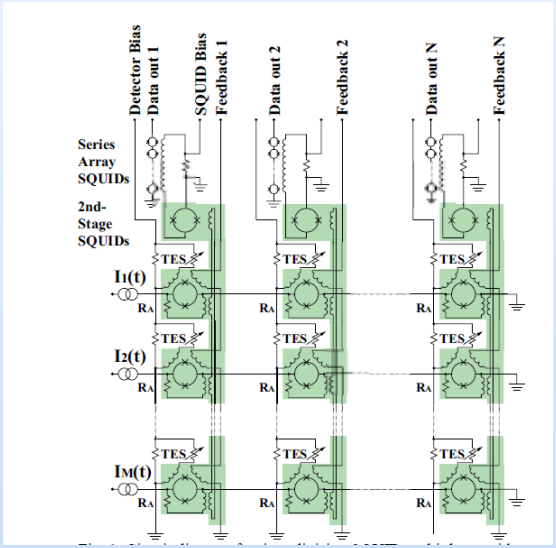
Readout for Superconducting Direct-Detector Arrays

K.D. Irwin (2001)



FDM (TES and MKIDs)

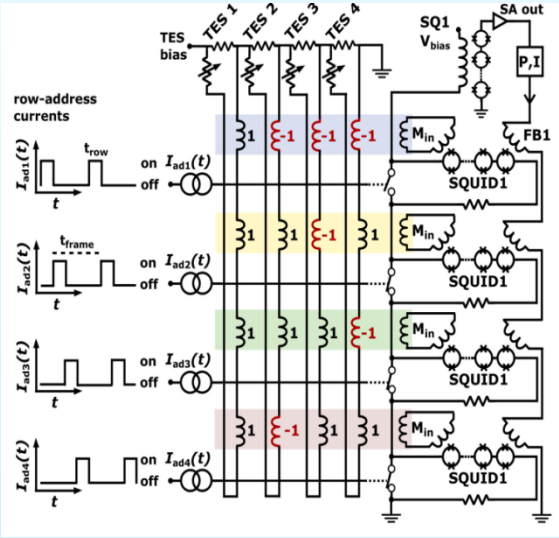
- Direct FFT analysis , Simple!
- Digital components at room temperature



TDM (TES)

- Low noise
- Low power

Niemack (2016)

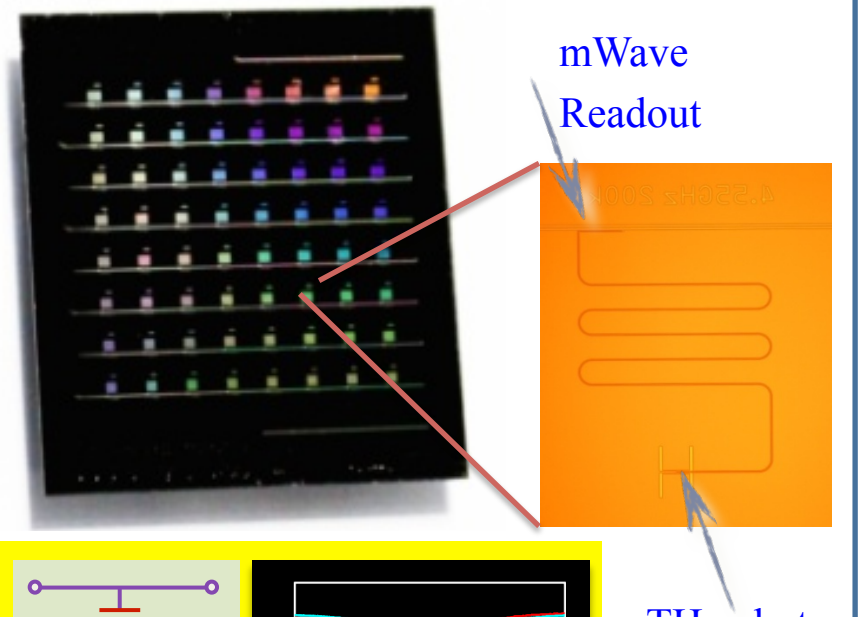


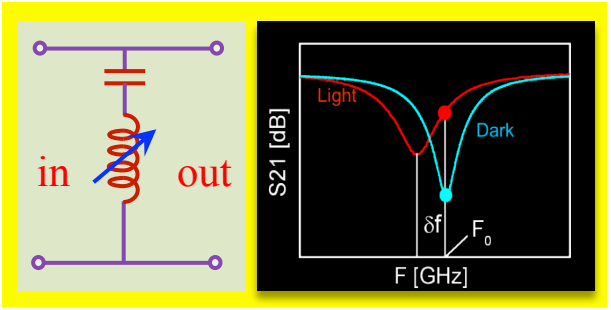
CDM(TES)

- Low cross-talk and
- the 1/f knee suppressed

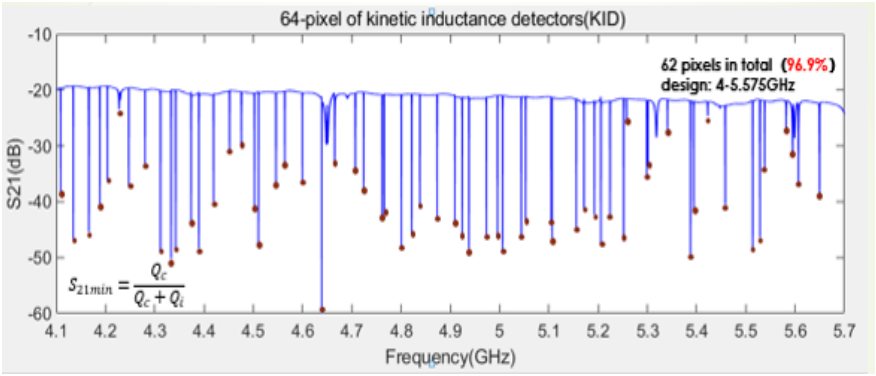
MKIDs: basic concept

Superconducting MKIDs



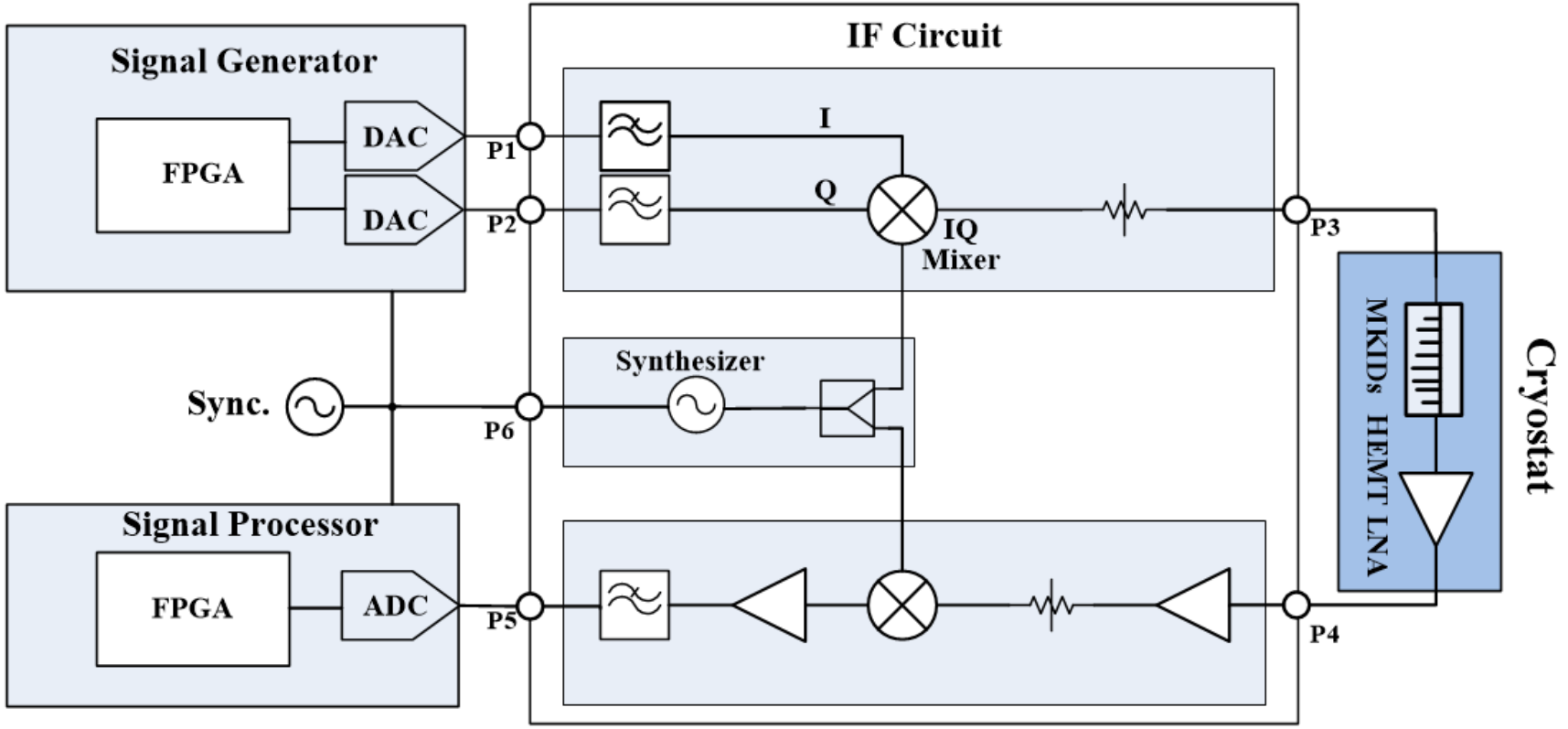


THz Photon gives rise to change in Kinetic inductance and resistor, therefore, change in resonance frequency and Q



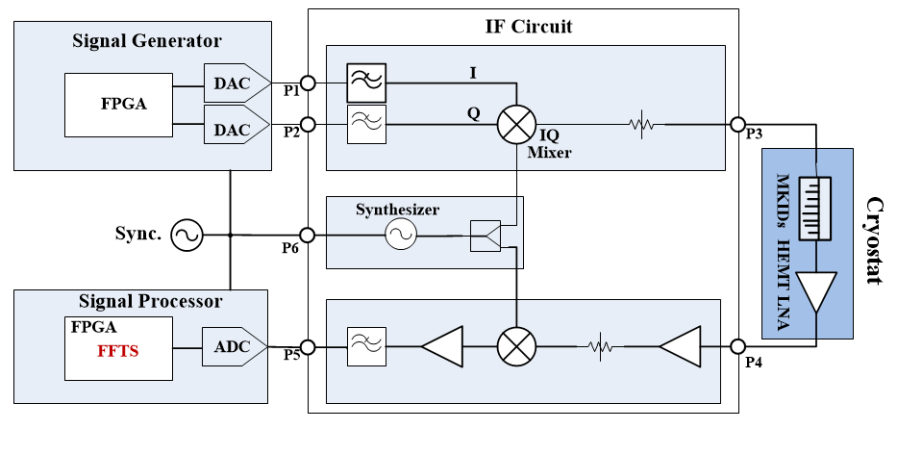
- MKIDs： design of different resonance frequency and high Q
- MKIDs Coupled to One transmission line
- Amplitude and phase of resonators readout through FDM circuit to detect incident THz signal

FDM readout Circuit for MKIDs

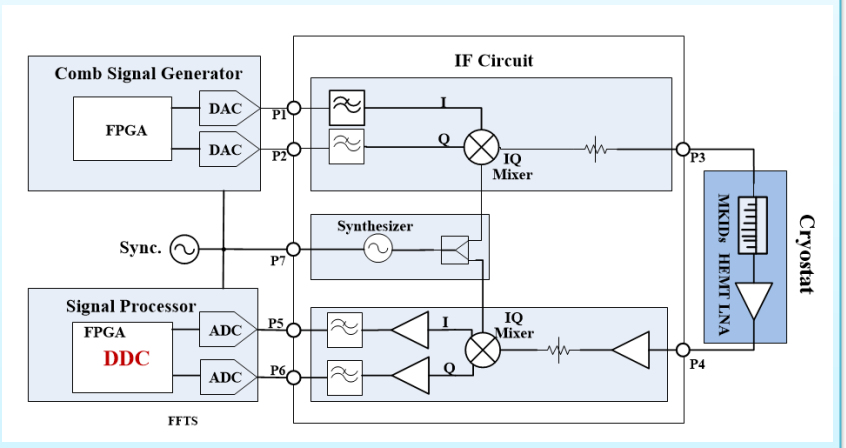


- Signal generator (FPGA and DAC）
- IF circuit (up-converter and down-converter, amplifier and filter) low temperature and room temperature)
- Signal processor(FPGA and DAC）
- Sync(LO and digital clocks）

MKID FDM readout



- Signal generator: FPGA + DAC （comb signals）
- Signal processor: FPGA + ADC (FFT spectrometer)
- Spectrum analysis straightway
- Length of FFT limits analysis precision of comb frequency
- Improve frequency resolution leads to decrease of time resolution, therefore increasing readout time
- ✓ Suits for integral flux application and imaging detection



- Signal generator: FPGA + DAC
- Signal processor: FPGA + ADC (Digital Down Converter[DDC] channelize)
- Improves analysis precision of comb frequency through DDC
- Improves time resolution
- Occupies more logic source of FPGA
- ✓ Suits for cosmic ray and photon detection

MKID FDM readout

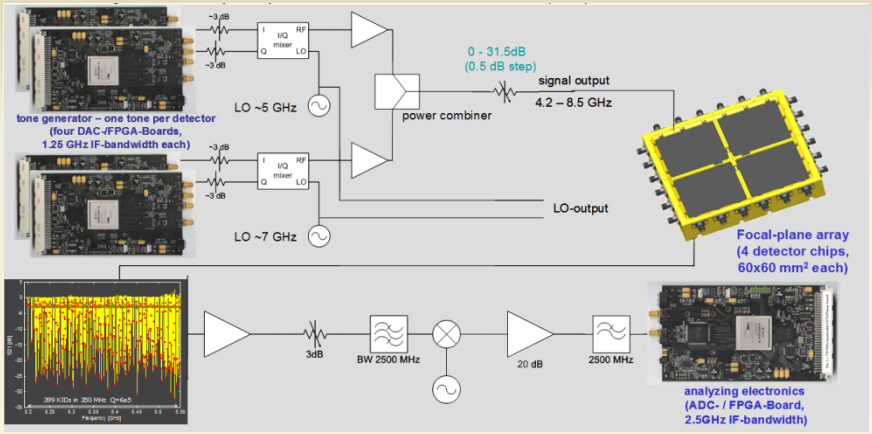
Instrument	Waveband	Pixel Number	FDM Readout	
			Method	Hardware
APEX-A-MKID	**350/850μm**	**25000**	**FFT**	**DAC/ADC+FPGA**
CSO-MAKO	**350μm**	**500**	**FFT**	**DAC/ADC+GPU**
IRAM–NIKA2	**1250/2000μm**	**4000/1000**	**DDC**	**DAC/ADC+FPGA**
LMT–TolTEC	**1100μm**	**3600**	**DDC?**	**DAC/ADC+FPGA**
BLAST–TNG	**200 to 600μm**	**2344**	**DDC**	**DAC/ADC+FPGA**
DARKNESS	**0.8 to 1.4μm**	**2900**	**FFT+DDC**	**DAC/ADC+FPGA**
CSO-MUSIC	**850/1100/1300/ 2000μm**	**576**	**DDC**	**DAC/ADC+FPGA**

FDM readout

MUSIC: Roach(FPGA) +DAC/ADC

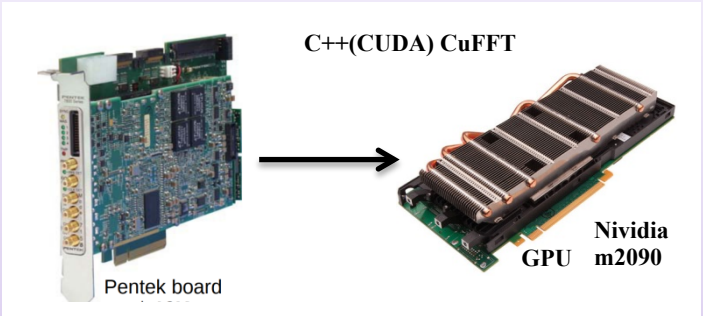
readout by DDC

A-MIKD : (DAC+FPGA) +FFTS



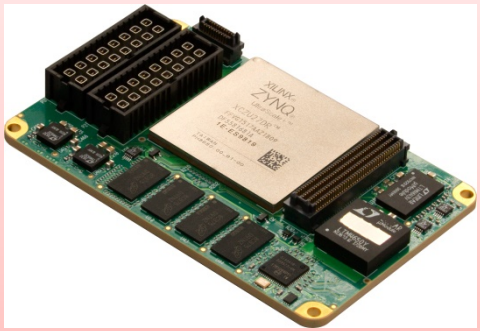
readout by FFTS

MAKO: Pentek(DAC/ADC) +GPU

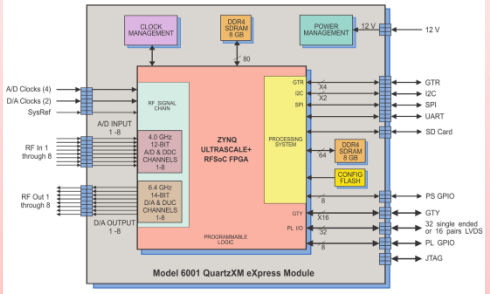


readout by CuFFT

RF SOC [ADC +DAC+FPGA (ARM Processor)]

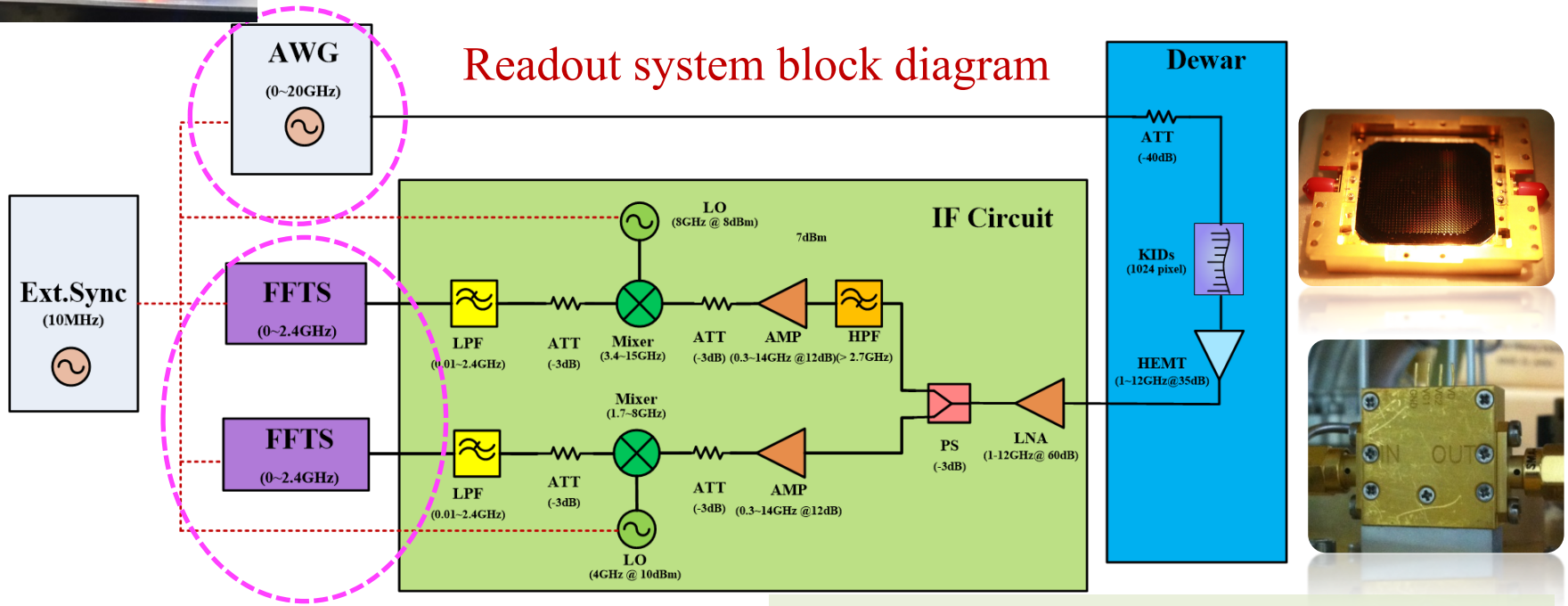


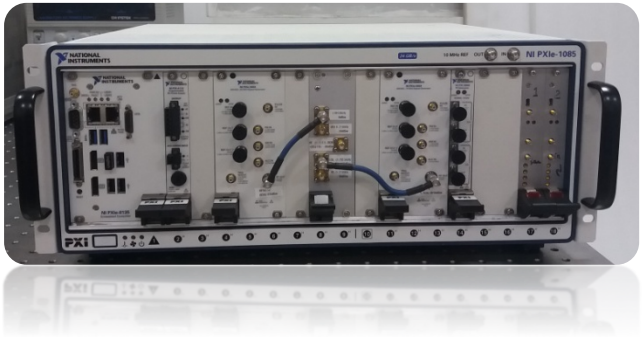
Pentek Model 6001



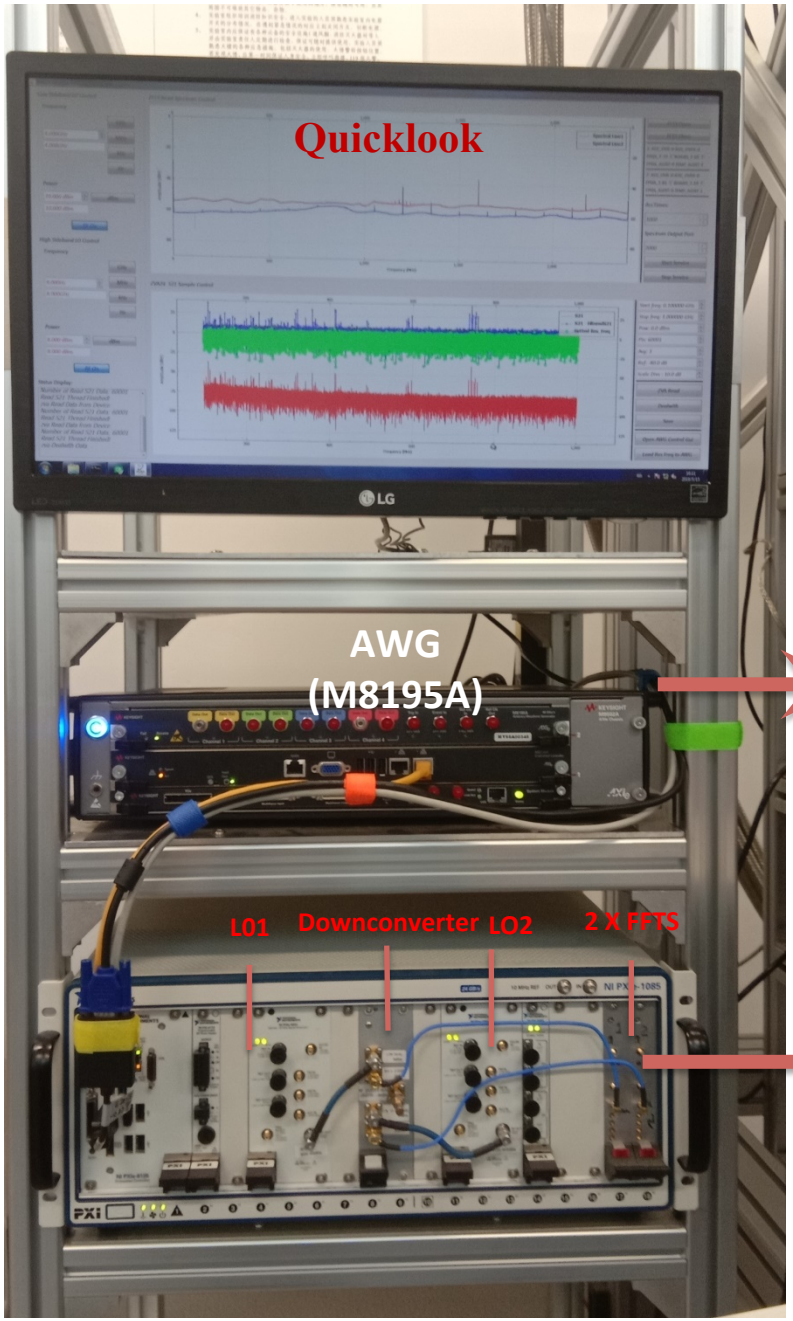
8ADC +8DAC+FPGA
(ARM Processor)

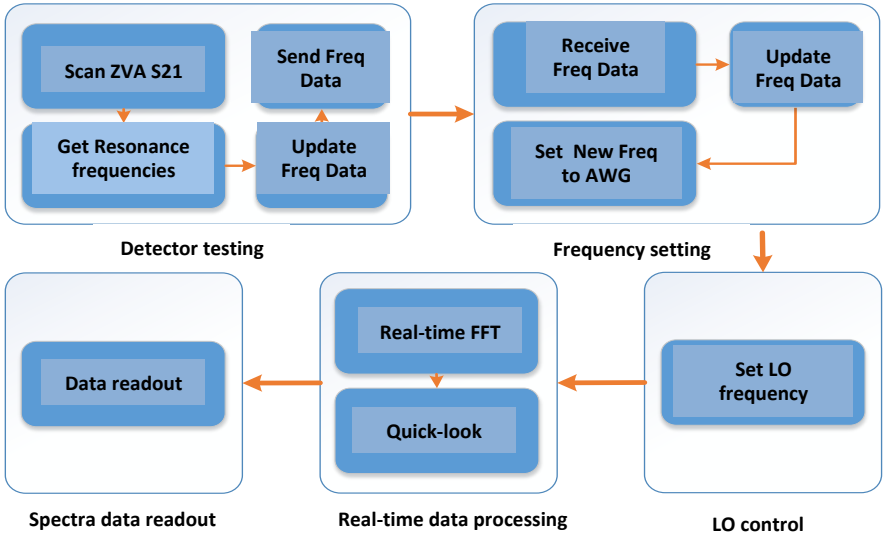
FDM readout for TeSIA MKIDs

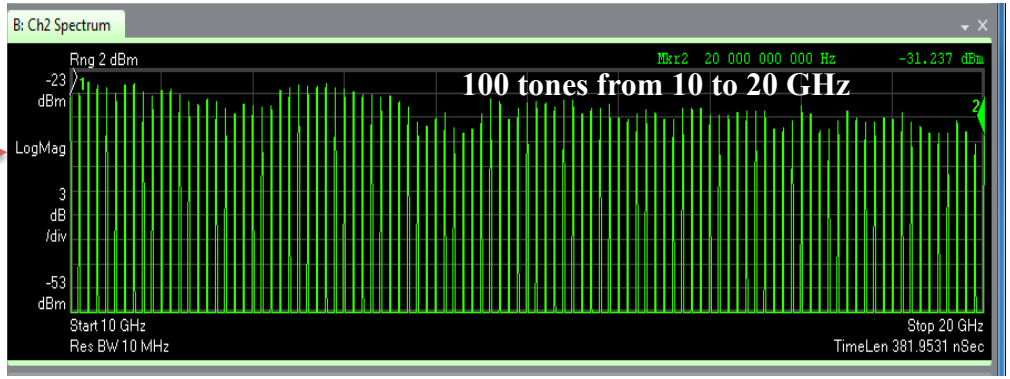


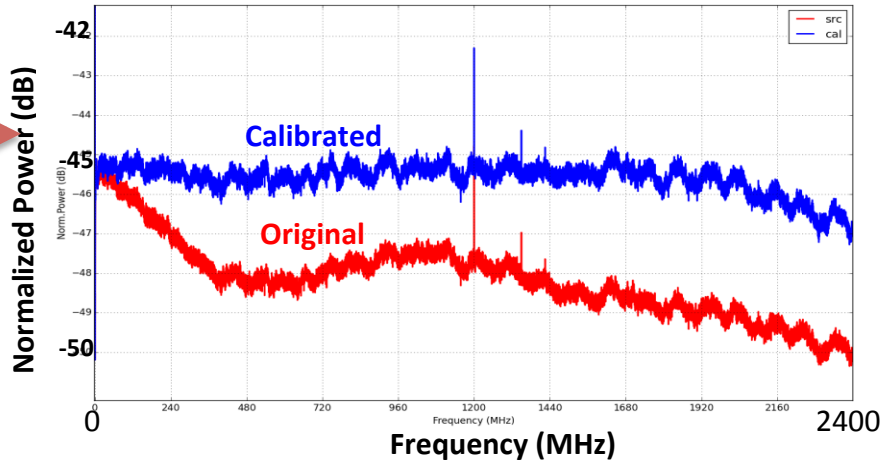


- Signal Generator：Commercial AWG(0-20GHz，80dBc SFDR）
- IF ： 4~8GHz,Two channel down converter
- Processor type : FFTS（2.4GHz x 2 ）
- Readout rate ： up to 100Hz
- Ext. Sync: 10MHz


Quicklook
AWG
(M8195A)
LO1
Downconverter
LO2
2 X FFTS


Scan ZVA S21
Send Freq Data
Get Resonance frequencies
Update Freq Data
Detector testing
Receive Freq Data
Update Freq Data
Set New Freq to AWG
Frequency setting
Data readout
Spectra data readout
Real-time FFT
Quick-look
Real-time data processing
Set LO frequency
LO control


B: Ch2 Spectrum
Rng 2 dBm
Mkr2 20 000 000 000 Hz
-31.237 dBm
-23 dBm
LogMag
3 dB /div
-53 dBm
100 tones from 10 to 20 GHz
Start 10 GHz
Res BW 10 MHz
Stop 20 GHz
TimeLen 381.9531 nSec


Normalized Power (dB)
-42
-45
-50
Calibrated
Original
src
cal
0
240
480
720
960
1200
1440
1680
1920
2160
2400
Frequency (MHz)


THANK YOU!

AWG M8190A

- Sampling speed: 8 GS/s
- Bandwidth: 3.2 GHz
- DAC : 14bit (90dBc SFDR)
- Memory: 2GB

AWG 8195A

- Sampling speed: 65 GS/s
- Bandwidth: 20 GHz
- DAC : 8 bit (80dBc SFDR)
- Memory: 16 GB