**Readout electronics**

Our readout scheme uses IQ mixing technique.

1. In-phase and quadrature of probe microwaves are generated by an FPGA and up-converted.
2. The microwaves transmitting through the resonators are down-converted and divided into I and Q microwaves.
3. The I and Q microwaves are mixed with cos(f0 + df) and sin(f0 + df), respectively, and averaged over certain length of time. This process can be written as

   \[ I : \frac{1}{T} \int_{0}^{T} a_{m} \cos(\omega_{0} t + \Delta \omega t) \cos(\Delta \omega t) \, dt = \cos(\omega_{0} t + \Delta \omega t) \]

   \[ Q : \frac{1}{T} \int_{0}^{T} a_{m} \sin(\omega_{0} t + \Delta \omega t) \sin(\Delta \omega t) \, dt = \sin(\omega_{0} t + \Delta \omega t) \]

The multiplication can be done in parallel and yields the phase and the amplitudes of all the resonators simultaneously and continuously.

**Transmission-xtype Micro Kinetic Inductance Detectors (MKIDs)**

- **half wave resonators**

We use the probing microwave that transmits a half wavelength resonator. The advantage of the half wavelength resonator over the quarter wavelength resonator is that the former can discard reflection and background of the probing microwaves, and offers clear microwaves passing through the resonators. The half wavelength resonator that is twice as long as the quarter wavelength resonator deteriorates sensitivity to the incident photons and the quasiparticle density. This can be compensated by making the width of the resonator small, reducing the volume and thus maintaining the quasiparticle density.

**The ABCD matrix of the half wavelength resonator can be written as**

\[ \begin{pmatrix} \tilde{A} & \tilde{B} \\ \tilde{C} & \tilde{D} \end{pmatrix} = \begin{pmatrix} 1 & i \tilde{X} \\ -i \tilde{X} & \tilde{X} \end{pmatrix} \begin{pmatrix} 1 & -1 \\ 1 & 1 \end{pmatrix} \]

where \( \tilde{A}, \tilde{B}, \tilde{C} \) and \( \tilde{D} \) are the matrix elements normalized to a characteristic impedance, \( \tilde{X} \) is a normalized impedance of the coupling capacitor, and \( \Phi \) is a product of the propagation constant and the length of the resonator. The scattering matrix element \( S_{11} \) is

\[ S_{11} = \frac{2}{2(\cos(\tilde{X}) + \sin(\tilde{X})) + j(2 - \sin(2\tilde{X}))} \]

The resonance occurs at \( 2\cos(\Phi) = -\tilde{X} \sin(\Phi) \), \( \Phi = \pi - \arctan(2/\tilde{X}) \).

Aluminum half wavelength resonators used to demonstrate the resonance frequency tracking. The transmission was measured at 0.32 K.

**Bandwidth**

DACs are able to produce sinuous waves with approximately a quarter of the clock rate (= 25 MHz).

\( \quad \text{Bandwidth should be about 50 MHz} \)

Sweep frequency and find several resonant peaks using our system and a network analyzer.

\( \quad \text{The peaks agree within bandwidth of 50 MHz} \)

**Irradiation of pulsed Millimeter-wave**

Aluminum MKIDs are irradiated with 96-GHz pulsed millimeter-waves (ON : 1 sec, OFF : 9 sec). The shifts in frequencies and amplitudes from two resonators were observed.

**Summary**

We have successfully demonstrated the MKID readout system with multiplexing and peak-tracking capability for large-dynamic-range measurements.

**Future plan...**

1. Increase the number of resonators (should be straightforward).
2. Evaluate uncertainties of the tracked frequencies due to the phase noise and \( \Delta f/df \).
3. Adjust time duration for phase monitoring (now 78 ms).