NbN 超伝導共振検出器の特性評価
-KIDsカメラ開発に向けて

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Astronomy in mm- and Submm-Wavelength

CMB

Tegmark et. al, 2003

Sub-mm Galaxy

A370 850, 450 um, (Smail et. al, 1997)

SSA 22 1100 um, (Tamura et. al, 2009)

Detector Development in ATC

-Kinetic Inductance Detectors
-Lens coupled antenna
-0.1K refrigerator
Detector Development in ATC

- Kinetic Inductance Detectors
- Lens coupled antenna
- 0.1K refrigerator

Double slot antenna and Si lens

0.1 K 無冷媒希釈冷凍機
(4K GM + 0.1K He3-He4 希釈冷凍機)
1 W @ 4 K
20 uW @ 0.1 K
Detector Development in ATC

- Kinetic Inductance Detectors
- Lens coupled antenna
- 0.1K refrigerator

Road map

<table>
<thead>
<tr>
<th>Year</th>
<th>Detector</th>
<th>Detector + Optics</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>120 pixel</td>
<td>9 pixel</td>
<td>multiplex readout</td>
</tr>
<tr>
<td>2011</td>
<td>-</td>
<td>256 pixel</td>
<td>10^{-17} (W/Hz^{1/2})</td>
</tr>
<tr>
<td>2012</td>
<td>-</td>
<td>1024 pixel</td>
<td>System</td>
</tr>
</tbody>
</table>

Kinetic Inductance Detectors

- Superconducting resonators operated in the microwave range
- Pair breaking detectors
Kinetic Inductance Detectors

-Superconducting resonators operated in the microwave range
-Pair breaking detectors

![Image of LC resonator]

Frequency dependence of $S_{21}$

Frequency ($\omega - \omega_0)/\omega_0$

Transmission (dB)

Sub-mm wave

Pair Breaking!!
Advantages of KIDs

- Simple fabrication
  One superconducting film and one etching process

Cross section of KIDs

Superconducting film

Substrate

Advantages of KIDs

- Simple fabrication
  One superconducting film and one etching process

- Simple system
  No bias line, only one CLNA

Signal generator
(4-8 GHz)
Advantages of KIDs

- Simple fabrication
  One superconducting film and one etching process
- Simple system
  No bias line, only one CLNA
- Frequency multiplexing (FFTS)
  Commercial products are available

- Broad-band coverage
  \( f > f_g \)
Advantages of KIDs

- Simple fabrication
  One superconducting film and one etching process
- Simple system
  No bias line, only one CLNA
- Frequency multiplexing
  Commercial products are available
- Broad-band coverage
  \( f > f_g \)
- High Sensitivity \( \leq 10^{-19} \) W/Hz\(^{1/2}\)

Origins of Noise

Generation-Recombination Noise (Barends, 2009)

\[
\text{NEP} \propto \left( \frac{N_{qp}}{\tau_{GR}} \right)^{1/2}
\]

\( N_{qp} \rightarrow \) low temperature \( (< \frac{T_c}{10}) \)

Gap energy vs T

\[
\frac{1}{N(0)V_{eff}} = \frac{1}{\Delta} - 2f(E) \sqrt{E^2 - \Delta^2} dE
\]

Number of quasi-particle vs T

\[
n_{qp} = 2N(0) \int_{\Delta}^{\infty} N(E) f(E) dE
\]
Origins of Noise

Generation-Recombination Noise (Barends, 2009)

\[ \text{NEP} \propto \left( \frac{N_{qp}}{\tau_{GR}} \right)^{1/2} \]

- \( N_{qp} \rightarrow \) low temperature \((<T_c/10)\)
- \( \tau_{GR} \rightarrow \) weak electron-phonon coupling \((\text{Al,Ta,Hf})\)
- epitaxial superconducting films

Measurement set-up

Barend, PhD. Thesis.
Summary

 NbNを使った超伝導検出器の測定。
 現状では、検出器雑音は超伝導膜の性質ではなく、
 誘電体内のTLSが支配。

 対策
 超伝導マイクロストリップKIDs (野口他, Mazin et. al, 2010)
 共振器の形状