KIDs- Kinetic Inductance Detectors for CMB

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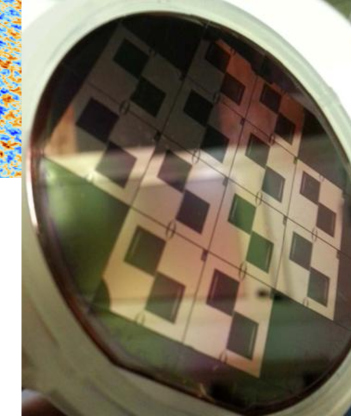
on behalf of the Italian CMB community

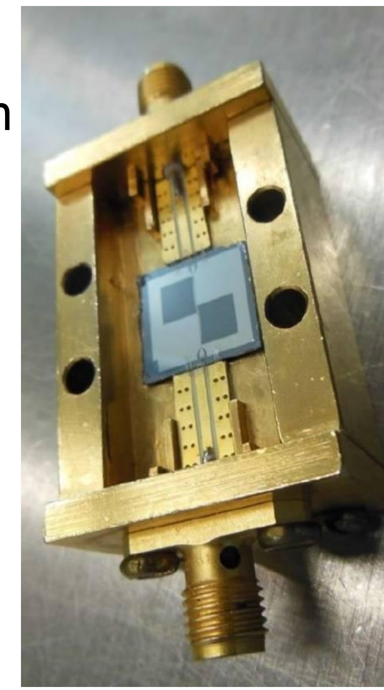
Overview

- KIDs: already used in astro experiments worldwide
- KIDs working principle
- KIDs technology - fabrication issues
- State-of-the-art in the italian CMB community

KIDs



- KIDs are Superconducting detectors, born in 2003 (JPL+Caltech)
- Detection range from submm-FIR (continuum) to optical- X (single photon capability)
- Suitable for large arrays and easily multiplexable



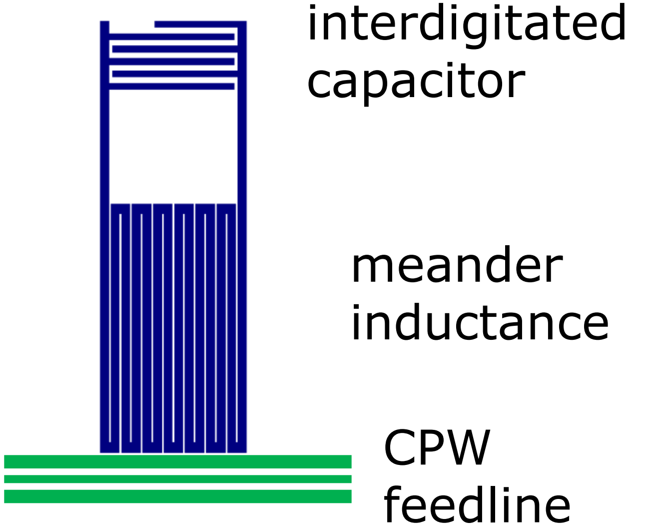
Already in use in many experiments for astronomy and astrophysics, ground-based or balloon-borne, in the sub-mm range:

- NIKA (300 KIDs) and NIKA2 cameras (4000 KIDs) for the IRAM telescope, 150-250 GHz
- Multiwavelength Sub/millimeter Inductance Camera (MUSIC) array (2000 KIDs) for the Caltech Submillimeter Observatory 150, 230, 290, and 350 GHz.
- Next Generation Blast (3000 KIDs)
- A-MKID camera for the Apex telescope

KID working principle

KIDs are:

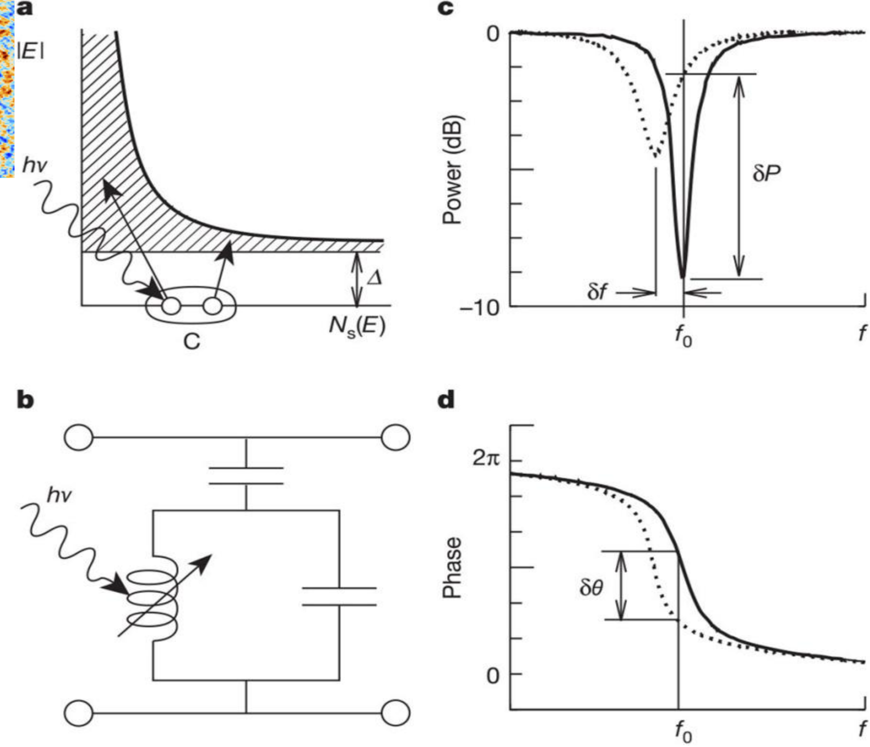
- superconductive microwave LC resonators (at 1-10 GHz)
- high Q factor (> 10^4)
- made with a superconducting thin film (Al, Ti, Al/Ti,...)
- coupled to a feedline (coplanar waveguide)
- working at cryogenic temperature (say <1K, depending on material)

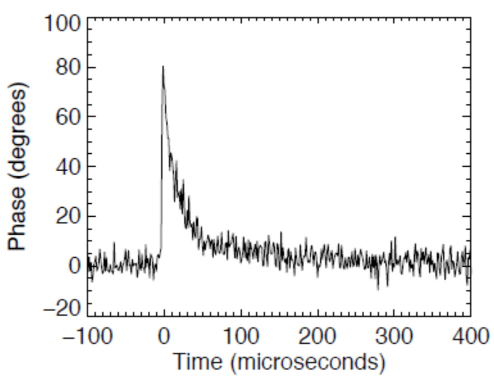


Advantages:
- only one thin film layer; easy fabrication

KID working principle

- "kinetic inductance" in a superconductor is determined by the number of Cooper pairs
- Cooper pairs are broken by impinging photons (if $h\nu > 2e\Delta$ - Δ is the superconducting gap) and change the kinetic inductance
- this produces a change in the resonance frequency and Q

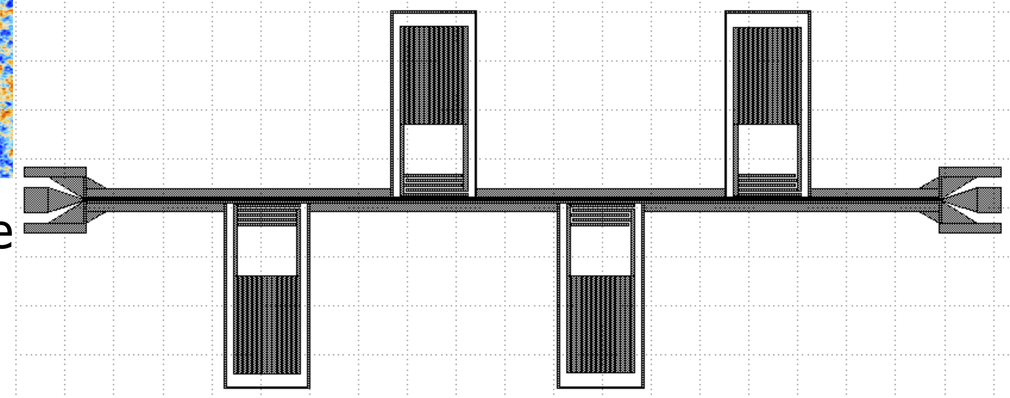




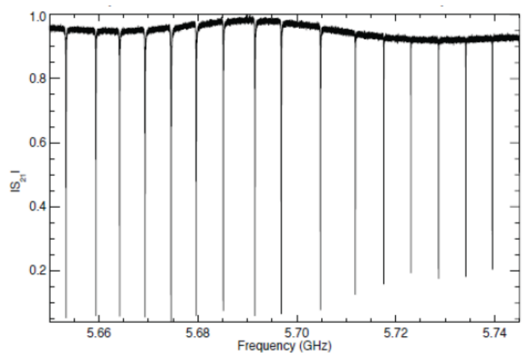
- use feedline to excite resonance and monitor changes

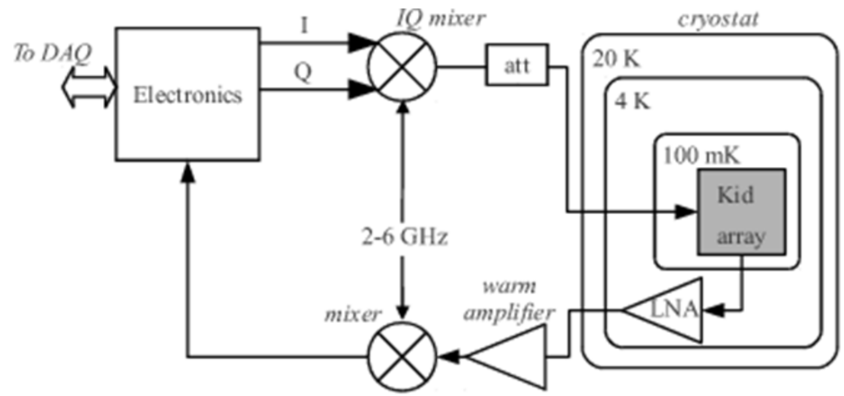
- output signal→ fast pulse in amplitude/phase
- optical coupling via antenna or direct absorption

KID working principle



- many resonators (hundreds) can be coupled to the same feedline
- each with a slightly different resonance
- all together excited by a frequency comb through the same feedline





Electronics:

Advantages:

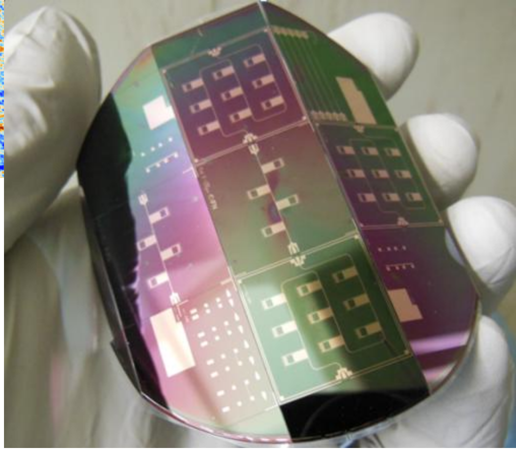
-easy multiplexing (frequency domain)

-reduced wiring and electronics

→ suitable for large arrays (thousands pixels)

- relatively simple readout

KID fabrication issues



Choose material:

- superconducting gap $\Delta \sim 1.75\ KT_c$ such that $h\nu > 2e\Delta$ in the frequency range of interest: Al, Ti, Ti/Al, Ti/TiN, ...
- resistivity must be suitable for impedance matching

Choose thickness:

- small thickness gives high inductance responsivity
- but changes film properties and Tc

Examples of films fabricated at CNR and tested at Sapienza

W-band:
75-110 GHz

Materials	Thick (nm)	T_c (K)	ν_c (GHz)	Band (GHz)
Al	20	1,43	104,0	150
Al	40	1,31	95,5	90
Al	80	1,28	93,2	90
Ti/Al	10/25	0,85	65,0	90
TiN_x	under investigation			

KID fabrication issues

Substrate: high resistivity silicon wafer (up to 4 inches diameter)

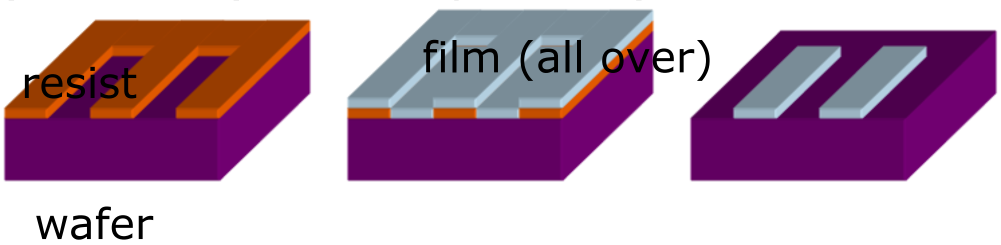
Thin film deposition (by evaporation/ sputtering/ reactive sputtering)

Pattern transfer: through resist mask and electron-beam lithography (100 keV e-gun)

Selected removal of the film: two techniques

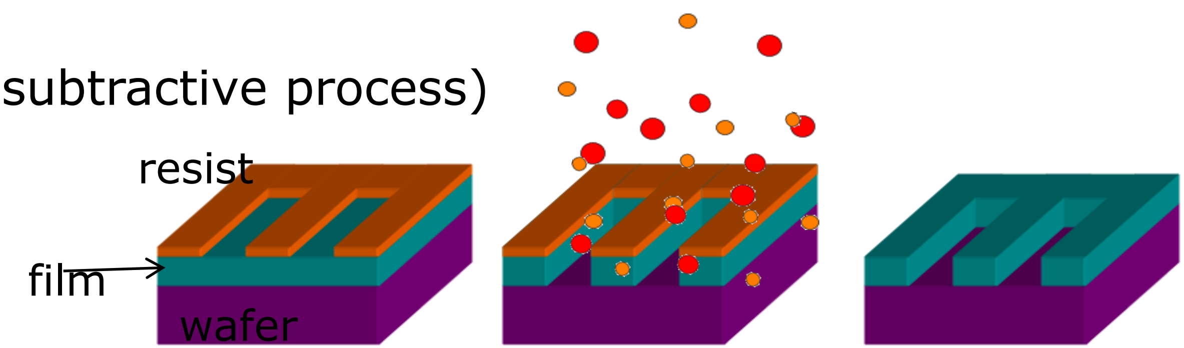
EBL Leica/Vistec EBPG 5000

1) Lift-off (additive process)



after resist removal, film remains only on selected areas.

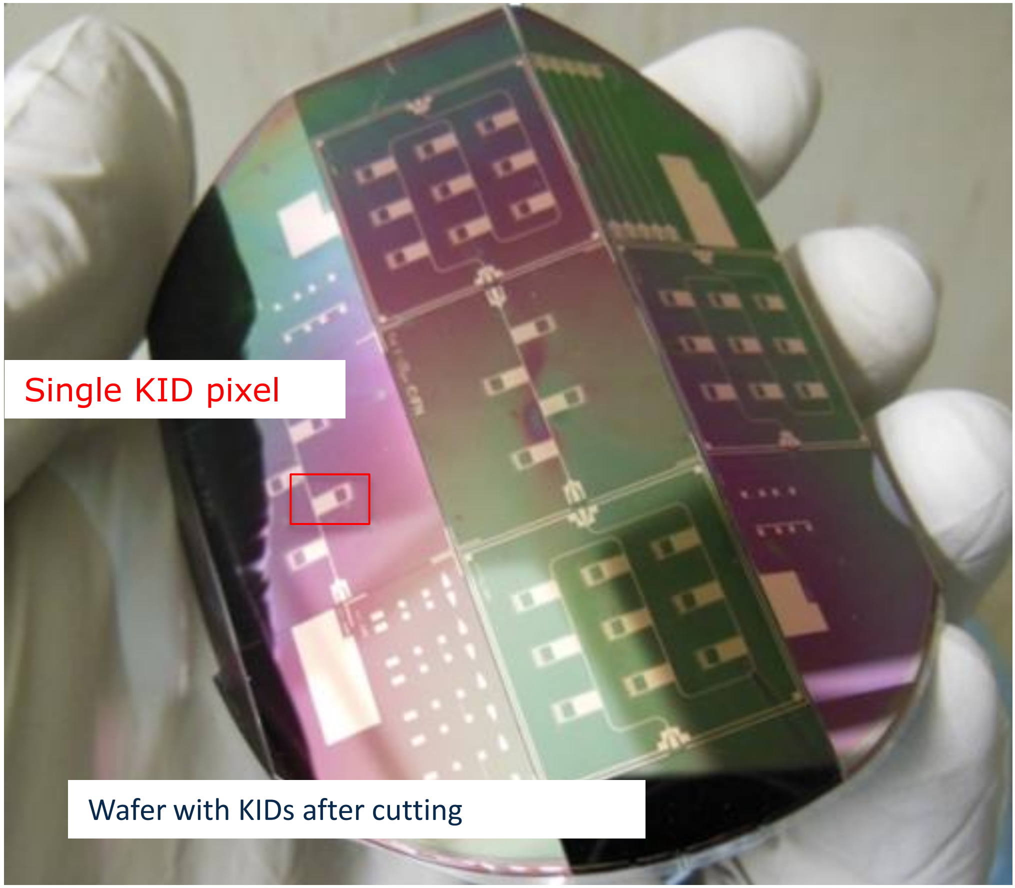
2) Etching (subtractive process)



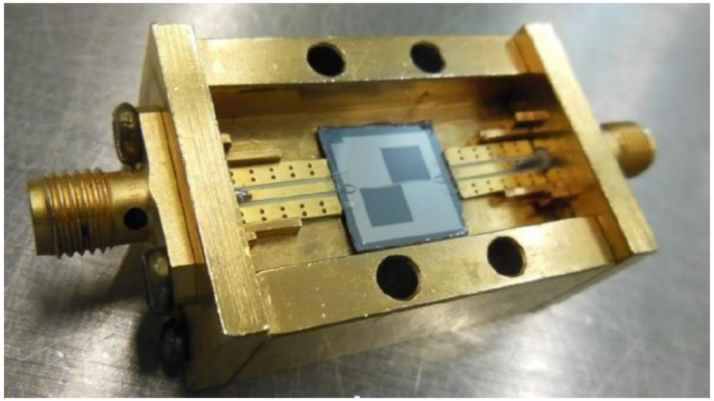
plasma removes unprotected film.

KID fabrication issues

Wafer dicing



Ultrasonic bonding in chip carrier



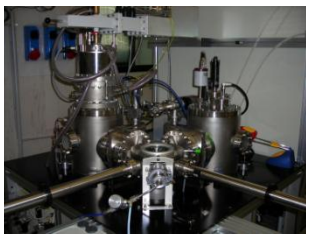
The fabrication facility at CNR-IFN, Rome

Cleanroom 300 m^2, class 100-1000 (ISO 5-6)

Thin-film deposition → Lithography [electron-beam] → Etching → Diagnostics

Thin-film deposition

evaporation, sputtering, CVD



Lithography [electron-beam]

optical UV 365 nm, electronic 100 kV


Etching

RIE Cl, F, Deep RIE

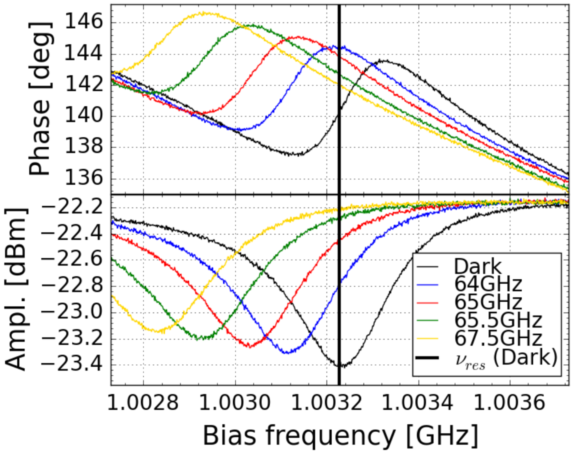


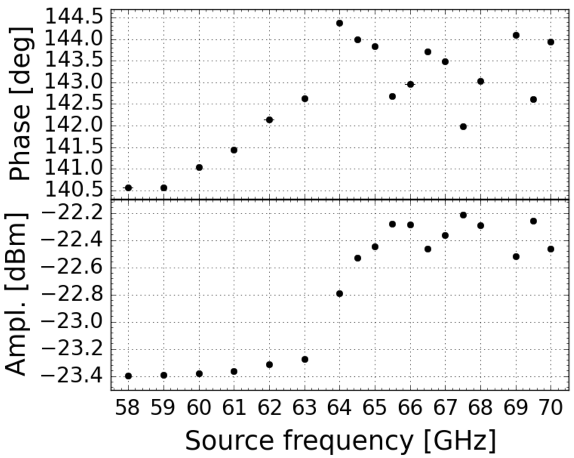
Diagnostics

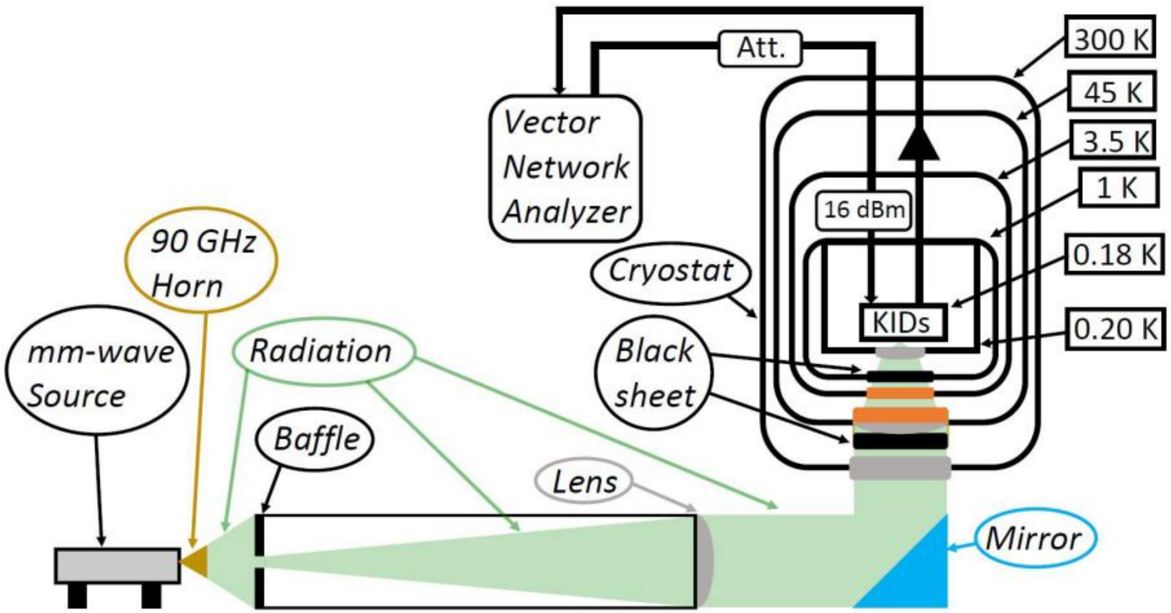
AFM, SEM


KIDs in Italy

Tests done at Sapienza on Ti/Al films by CNR



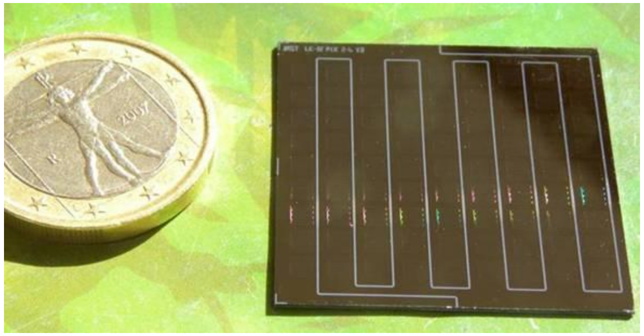


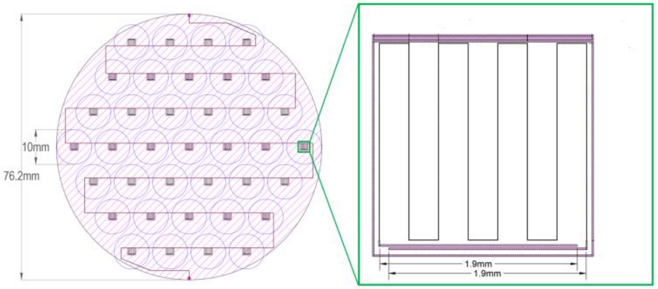


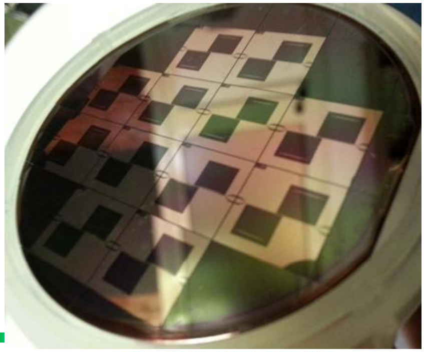
- Al KIDs succesfully tested down to 95 GHz
- Ti/Al KIDs are being developed for W-band; first tests show sensitivity down to 65 GHz

KIDs in Italy

- RIC project of INFN group V: first array of KIDs for mm-waves in Italy. Design and testing in Roma1, processing in FBK Calvo et al. 2010 Exp.Astron. (2010) **28**: 185–194.
- Collaboration between IFN-CNR and Sapienza continuing despite of the lack of official resources, and producing improved quality LEKID detectors.
- Recent proposals to ASI:
  - «Nuove idee di strumentazione scientifica per missioni future di Osservazione ed Esplorazione dell'Universo» – KIDS proposal, recoverec by ASI CdA (2015).
  - WP within Premiale ASI 2015 – Approved by Government.
- Recent proposals to INFN:
  - «6 progetti di ricerca per giovani ricercatori/ricercatrici» (2015): A. Cruciani, Roma1, MoBiKID: Characterization of KIDs for space, started.
- **Possible uses of Italian KIDs:**
  - **OLIMPO** (as validation test or even as main arrays; important qualification for space missions)
  - **Sardinia Radio Telescope** (array of 90 GHz KIDs)
  - Forthcoming **M5 CMB** space mission, Italy can provide part of the focal plane and readout, if KIDs technology selected.







Conclusion

- KIDs are successfully used worldwide for astronomy and cosmology
- In Italy, high-quality Al and Ti/Al KIDs are produced and operated
- With Ti/Al films, the operating frequency of 65 GHz, within the W-band, has been reached
- Ready for implementation in forthcoming experiments