Hermetic package for MEMS mirror

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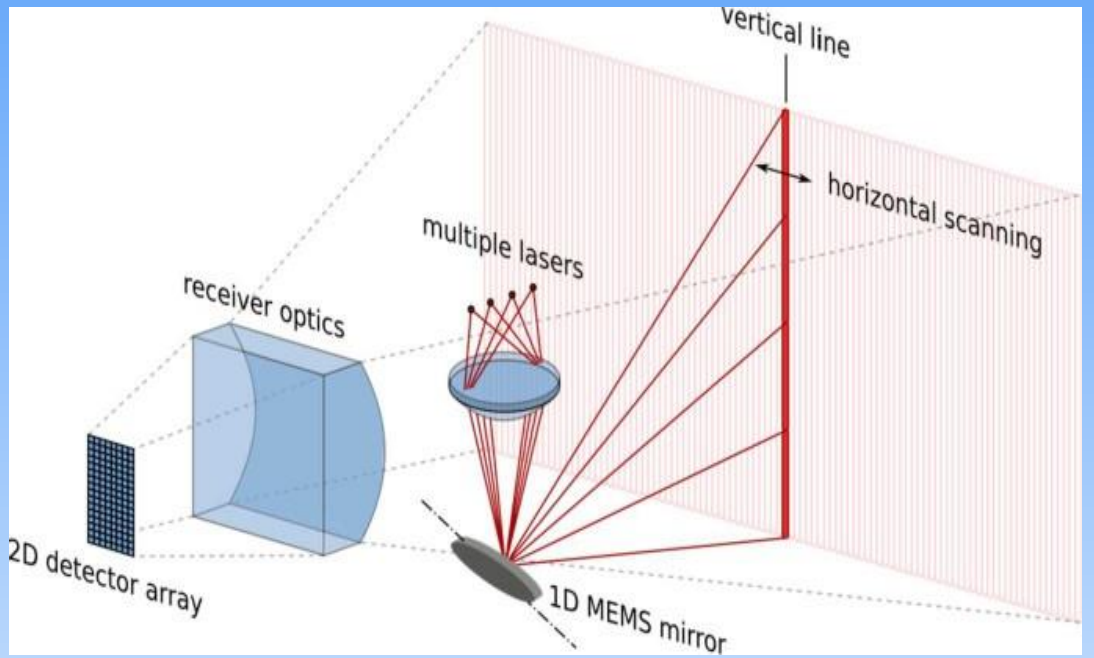
Outline

- Application cases
- Description of mirrors
- Package overview
- Packaging process:
  - Mirrors die attach
  - Wire bonding
  - Cap soldering
- Hermeticity testing

Main Application cases - LIDAR

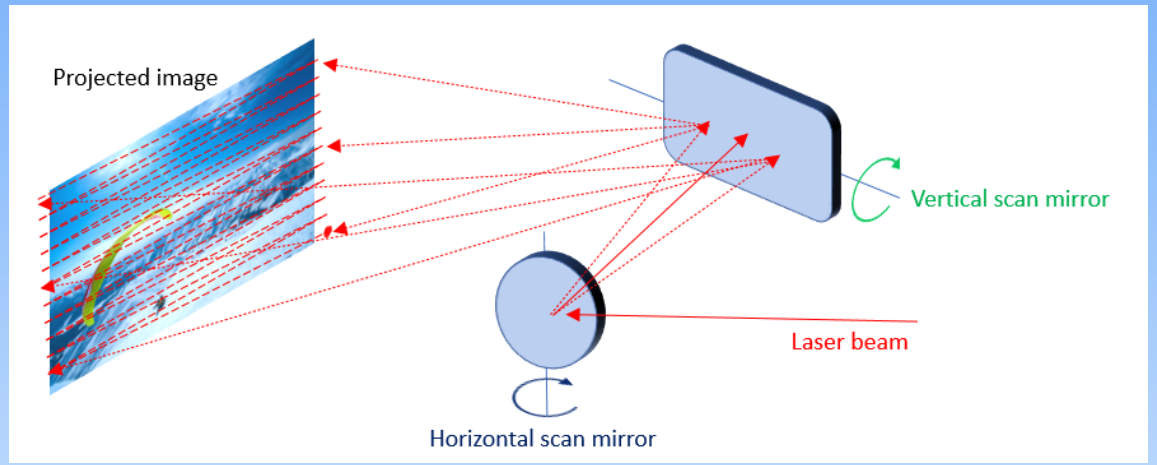
- Automotive or industrial application:
  - Description: single monoaxial micromirror used in LIDAR systems
  - Requirements:
    - **Key requirement:** Protection from external environmental conditions (hermetic sealing against humidity) to increase reliability
    - **Optional**: Low pressure atmosphere to increase Q-factor



Example of MEMS LIDAR system

Main Application cases – Glasses for AR

- Consumer application:
  - Description: monoaxial resonant micromirror in a raster scan projector used in AR glasses or HMDs
  - Requirements:
    - **Key requirements:**
      - Low pressure atmosphere to reduce power consumption
      - Small size to fit smallest form factor projectors
      - Low cost



Laser Beam scanning system based on 2 cascaded monoaxial micromirrors (fast mirror for horizontal scanning, slow mirror for vertical scanning)

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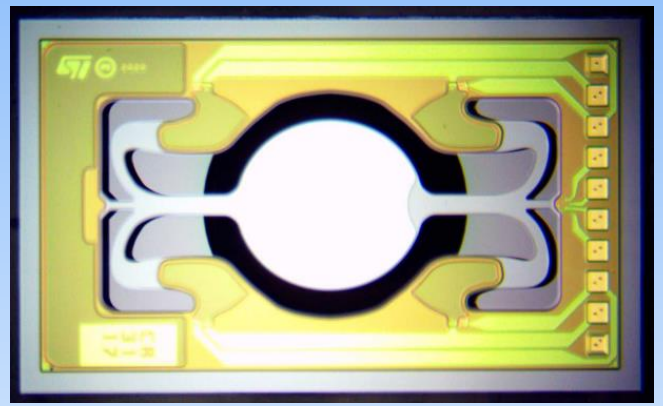
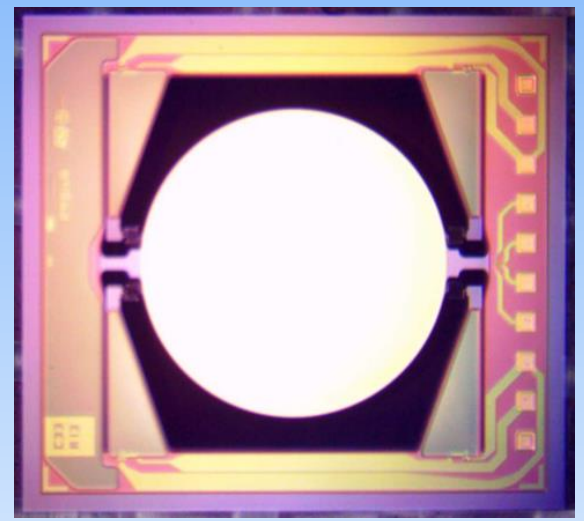
MEMS micro mirrors

- Die size: 4mm x 2.4mm
- Die Thickness: 0.67mm
- Mirror diameter: 1.1mm



- Die size: 5.5mm x 5mm
- Die Thickness: 0.9mm
- Mirror diameter: 3mm



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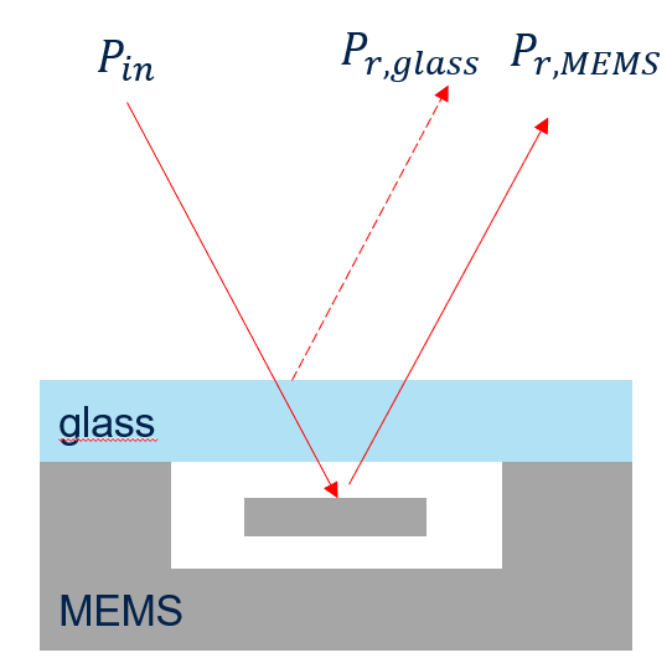
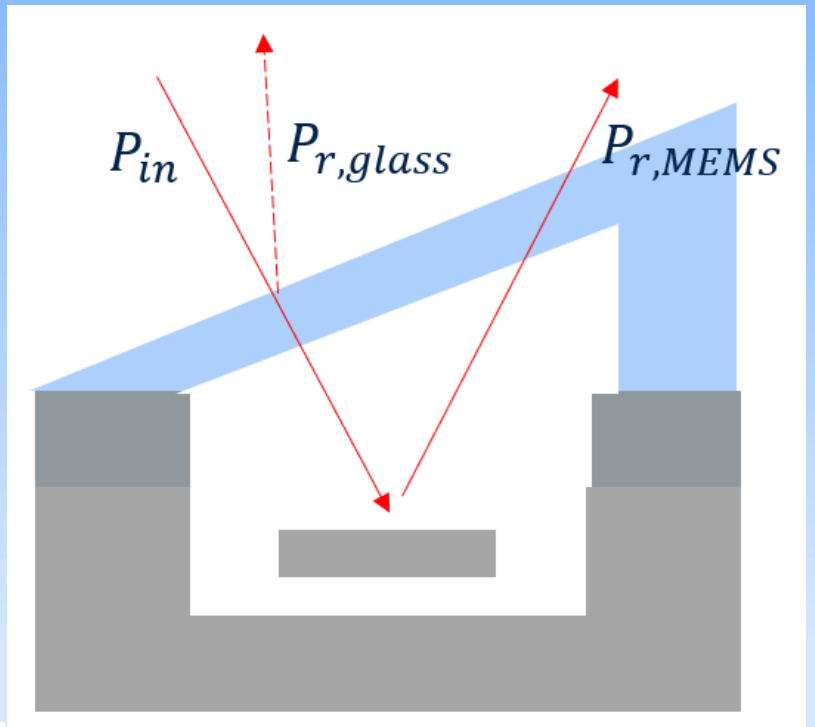
Spurious reflections

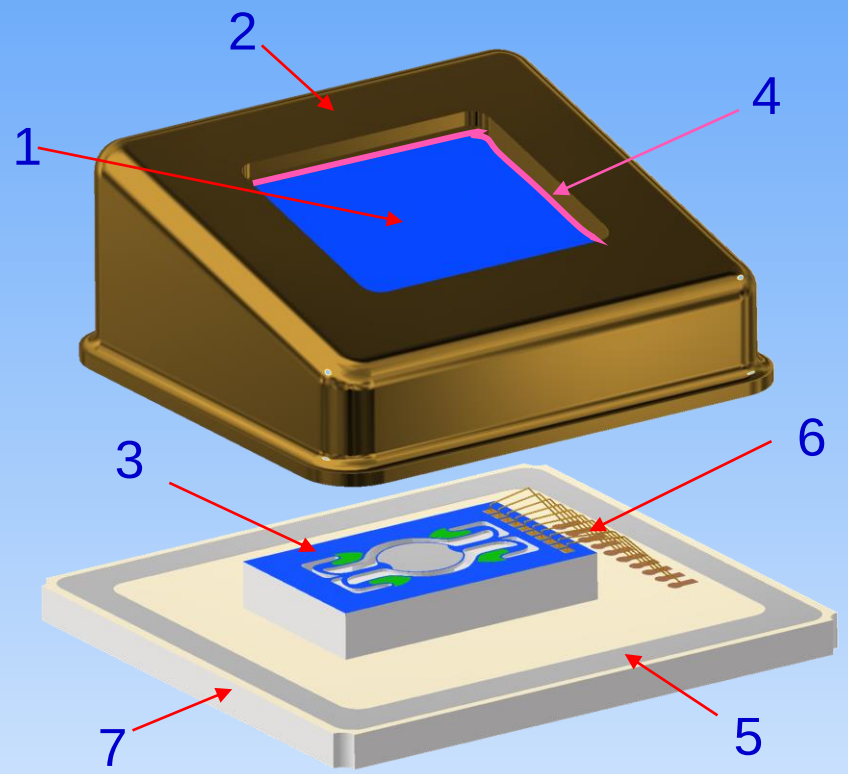
- Flat glass window generates a well-known issue of spurious reflection and ghost images, which is detrimental for projection image quality.



- Known solution: tilted cap to spatially separate between mirror and window reflections



Package Overview



ID	Name	Description
1	Glass protection Opto-Window	Borosilicate 200um D263T – eco compo compatible
2	Metal Cap body	Kovar 200um thickness Ni/Au plated
3	Micro-Mirror MEMS die	Housing dimension max 5.5X5.5X0.9mm
4	Glassfrit interface for Opto-Window sealing	Proper material with process Temp compatible with metal-cap material
5	Preform solder ring for Metal Cap to ceramic base sealing	Sn 96.5% Ag 3% Cu 0.5% (SAC305)
6	Wire Bonding interconnections to ceramic base fingers	Au wire 0.8mil
7	Ceramic 2L base with WB finger inetrconnections and LGA lands for SMD	Custom ceramic base for mirror die housingXY = 8.00X7.24mm thickness 0.50mm

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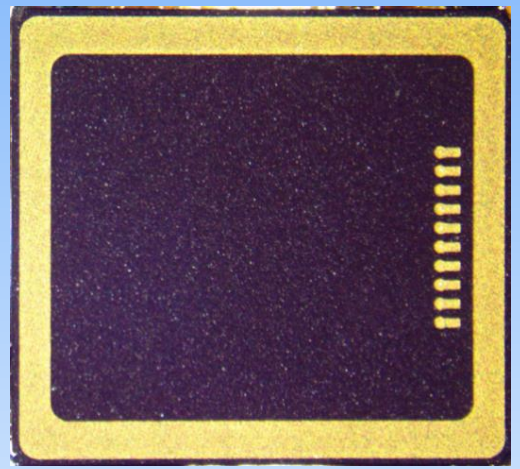
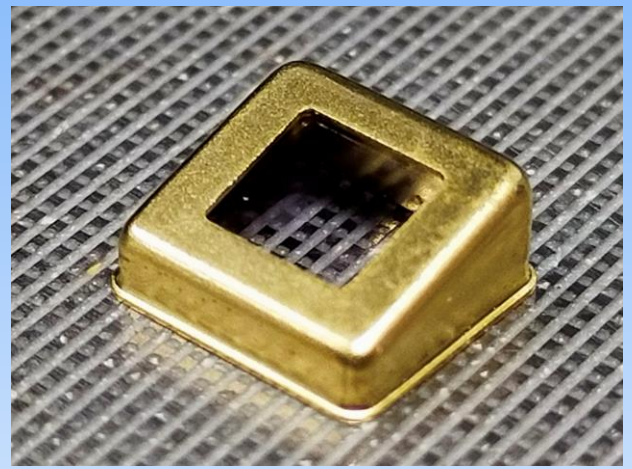
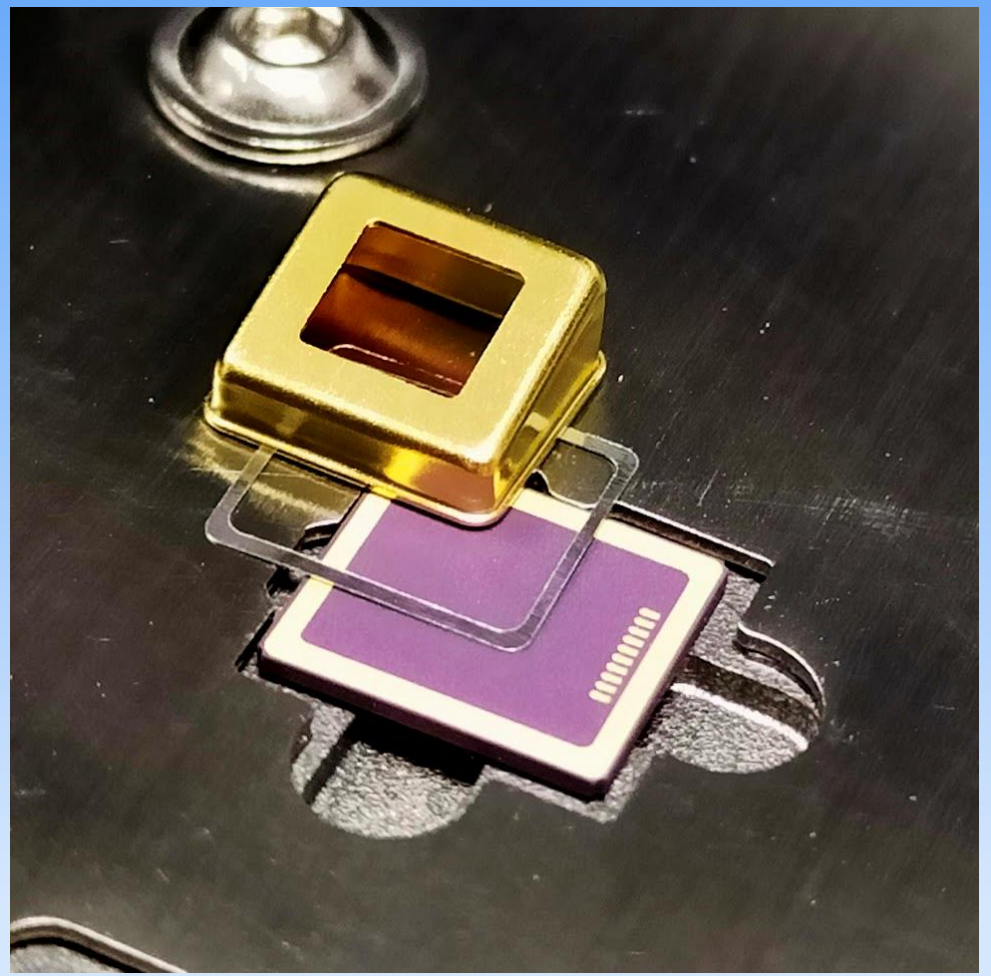
Package structure

- Ceramic chip carrier with solder ring
- Metal lid with sintered optical window
- Solder preform for sealing

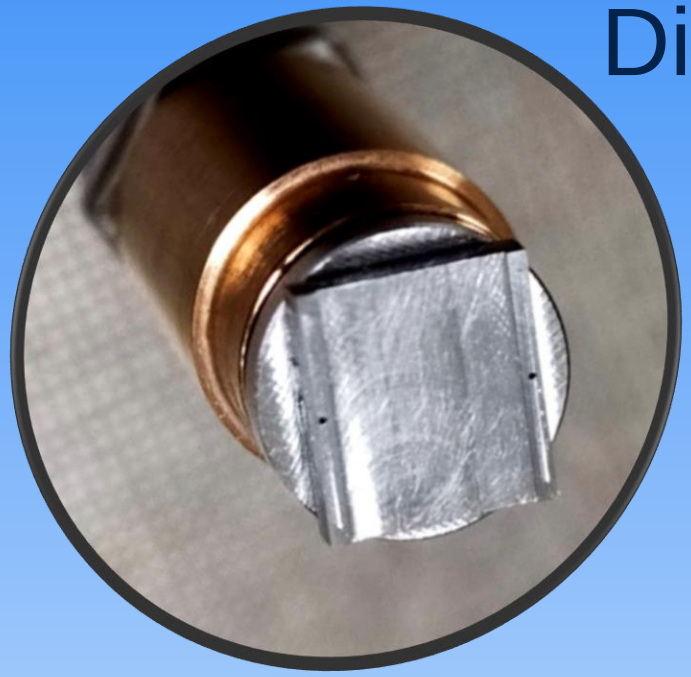


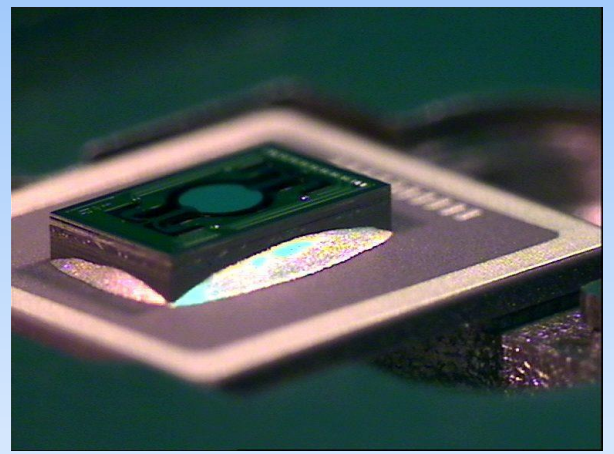


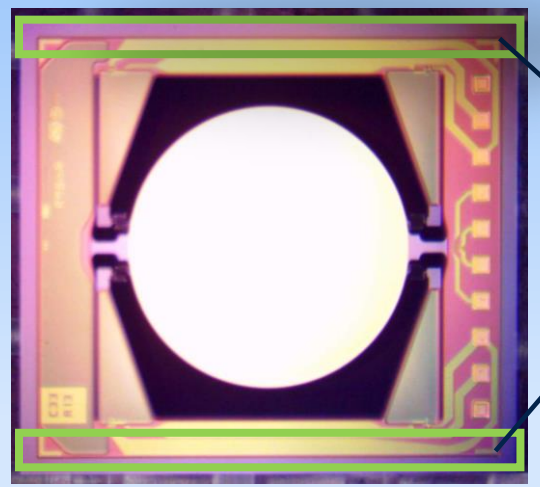


Die attach

- Specially designed die-collet tools to avoid touching membranes
- Gimbal head to adjust die parallelism
- Conductive epoxy, stable up to 300 °C, with low outgassing
- Shear test (MIL-STD-883-2, 2019.10): no detachment with 10 kgf applied force







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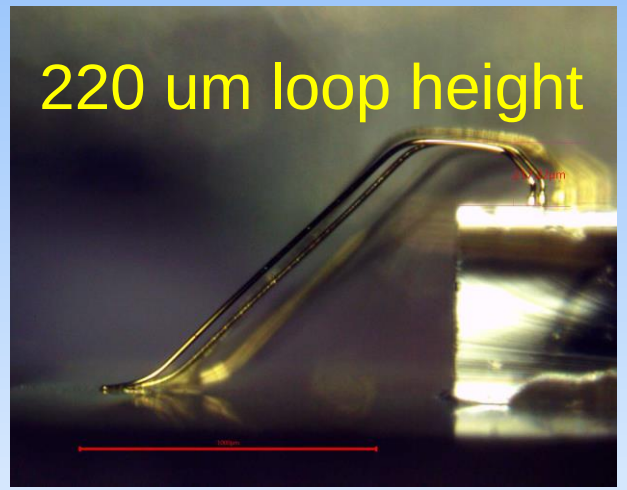
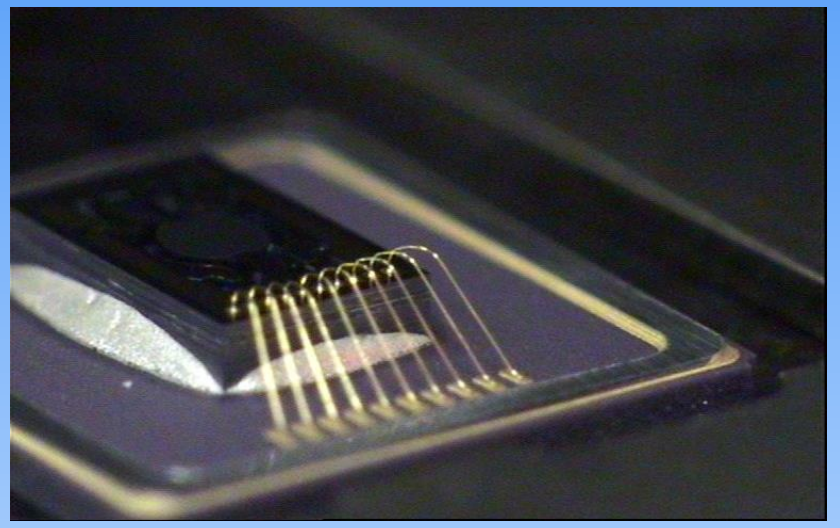
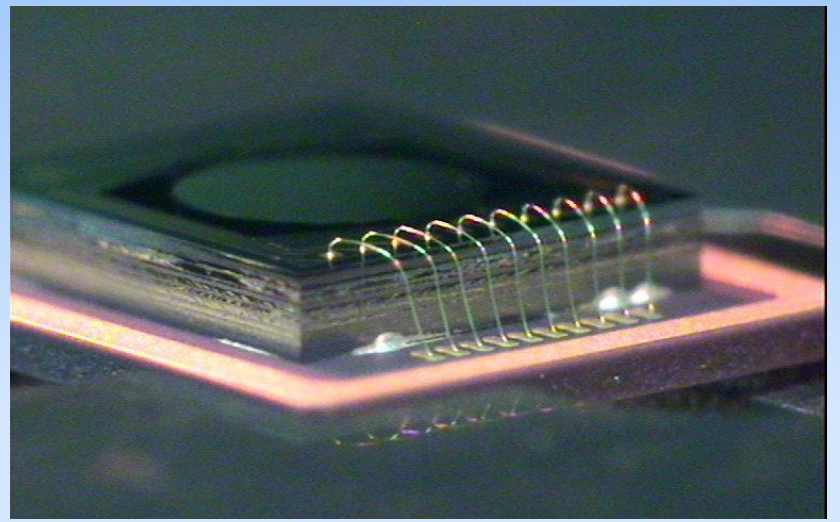
Wire bonding

- Automatic ball-wedge process with controlled loop to guarantee clearance from the cap
- 0.8 mil Au wire
- Pull test (MIL-STD-883-2, 2011.10): breaking force of 4.04 gf or higher after lid soldering thermal cycle







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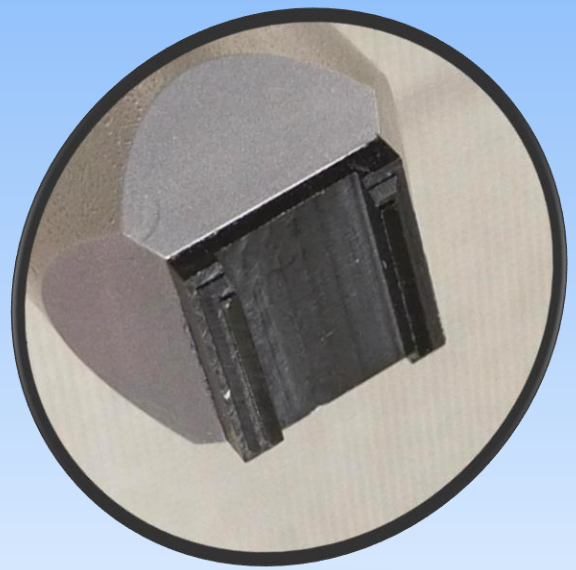
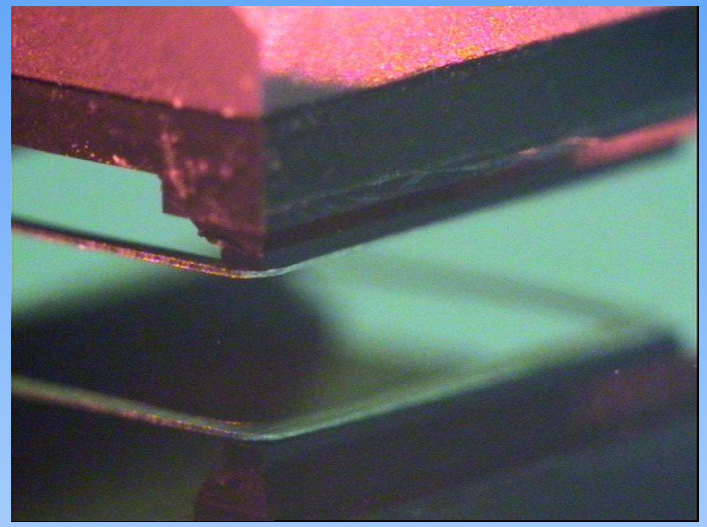
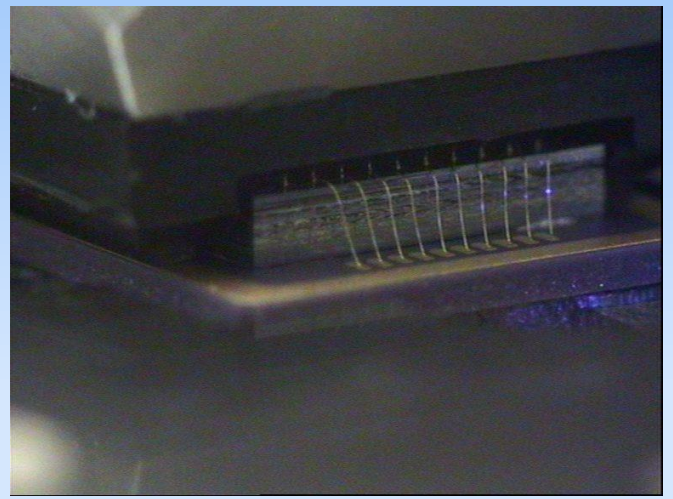
Preforms placement

- Specially designed pick-up tool to avoid interference with dice and bonds
- SAC305 preform aligned to package ring







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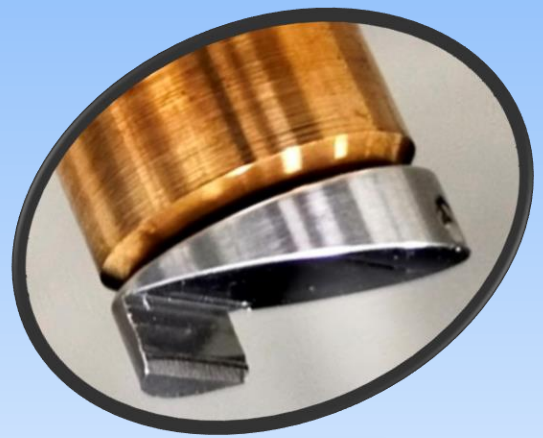
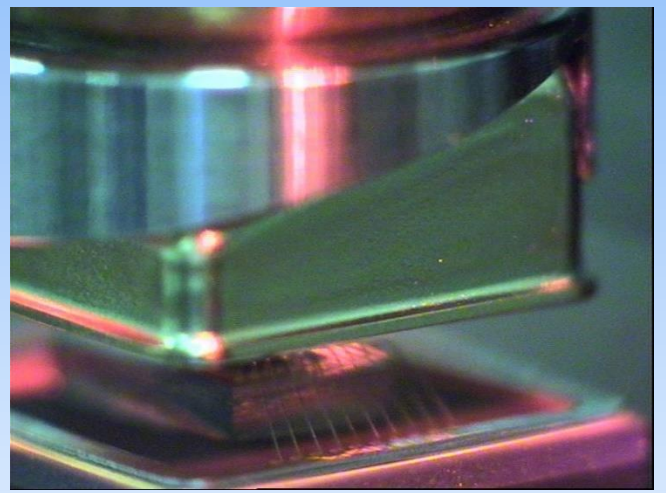
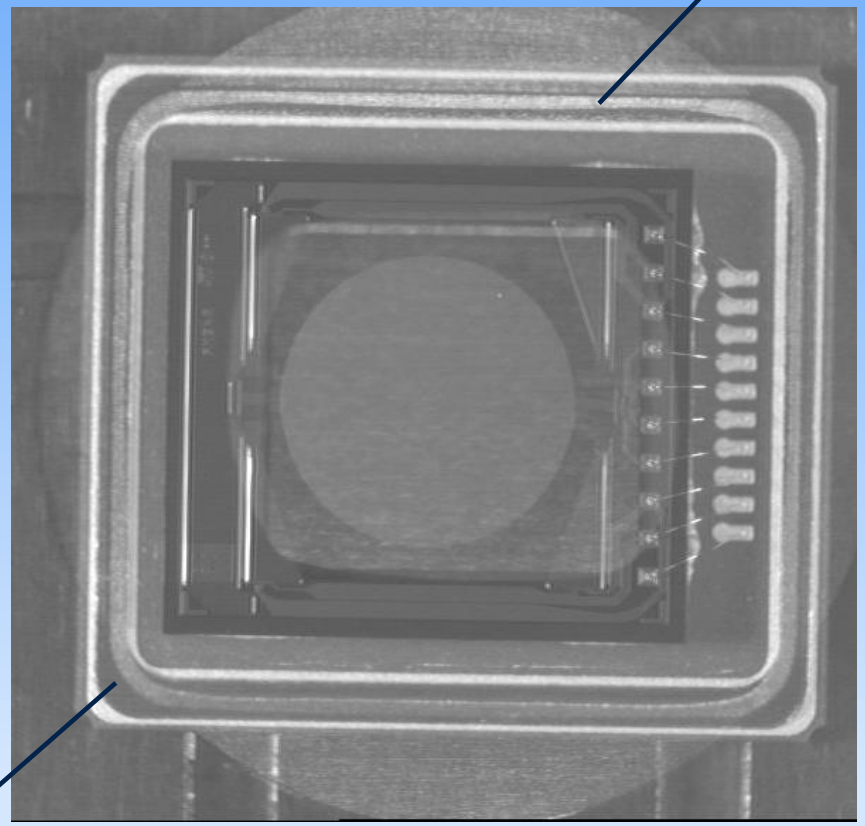
Cap placement

- Specially designed pick-up tool to handle the cap
- Gimbal to adjust parallelism
- Cap flat base aligned to the preform







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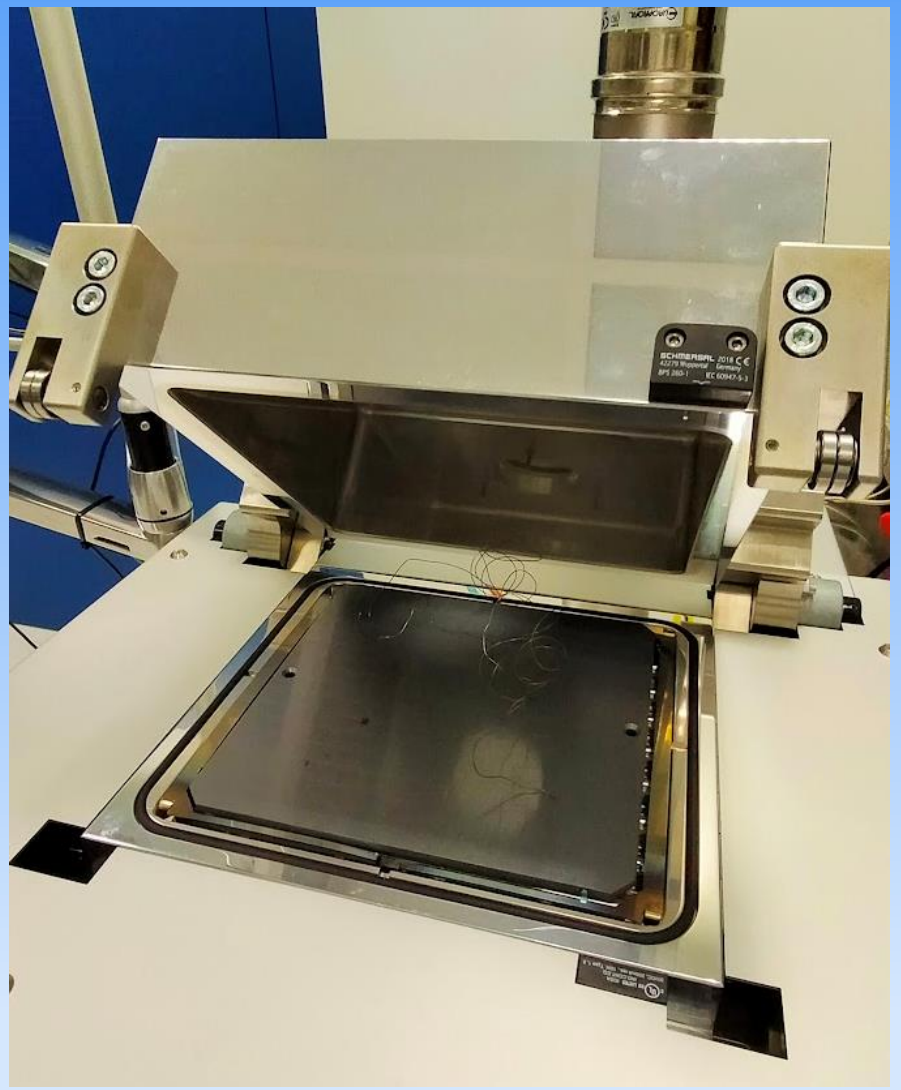
Reflow oven

- Programmable vacuum solder reflow system
- Vacuum to $<5*10^{-2}$ mbar
- Gas inlets for N_2, and formic acid with independent controllable flow
- Graphite plate
- Rapid heating system (up to 3.5 K/s)
- Cooling by forced N_2 flow



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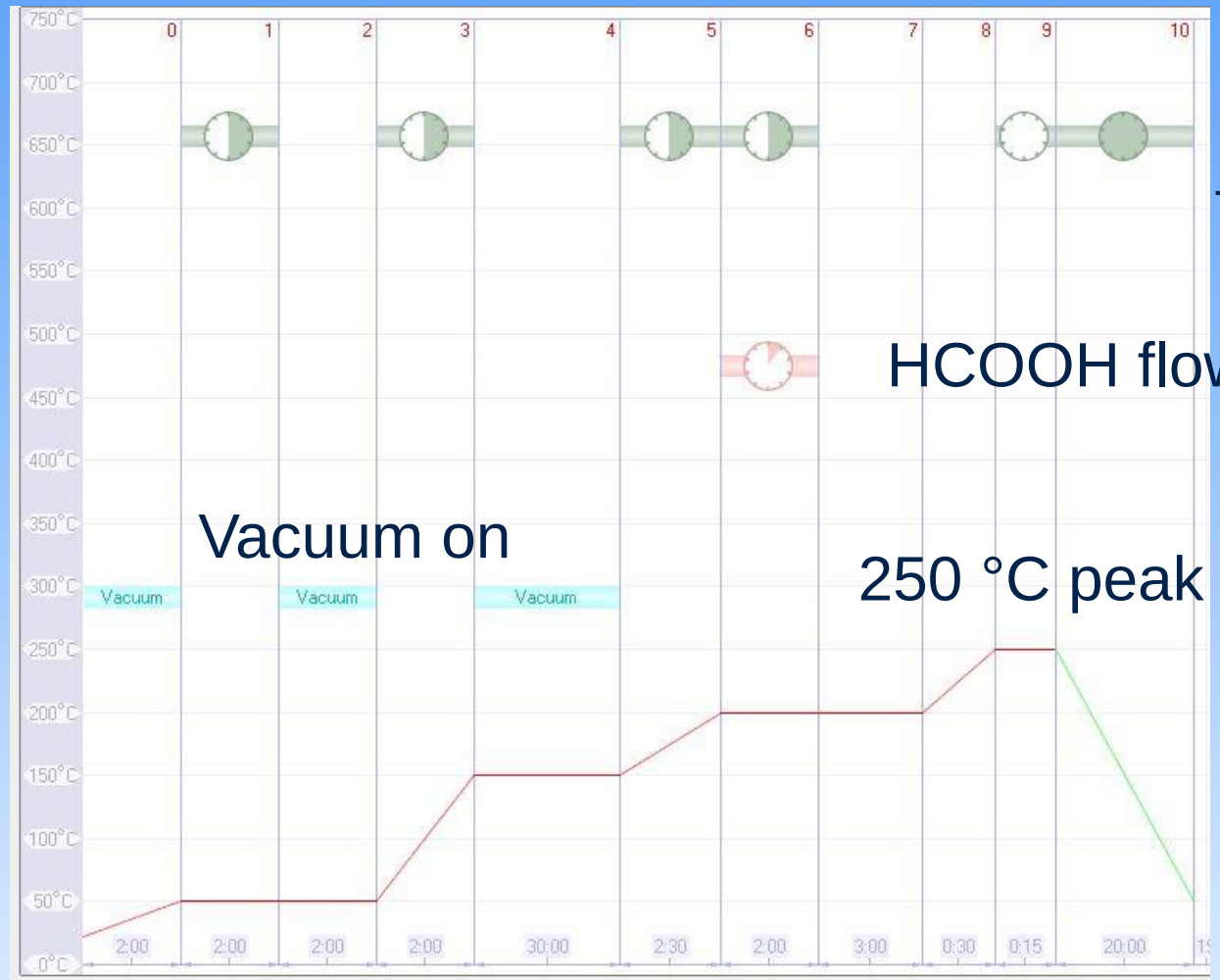
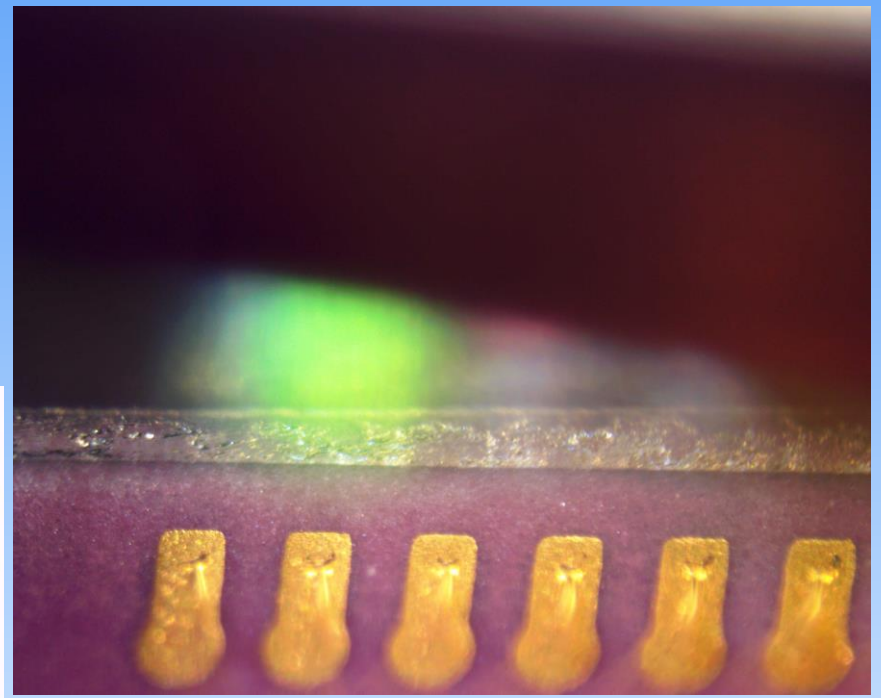
Reflow profile

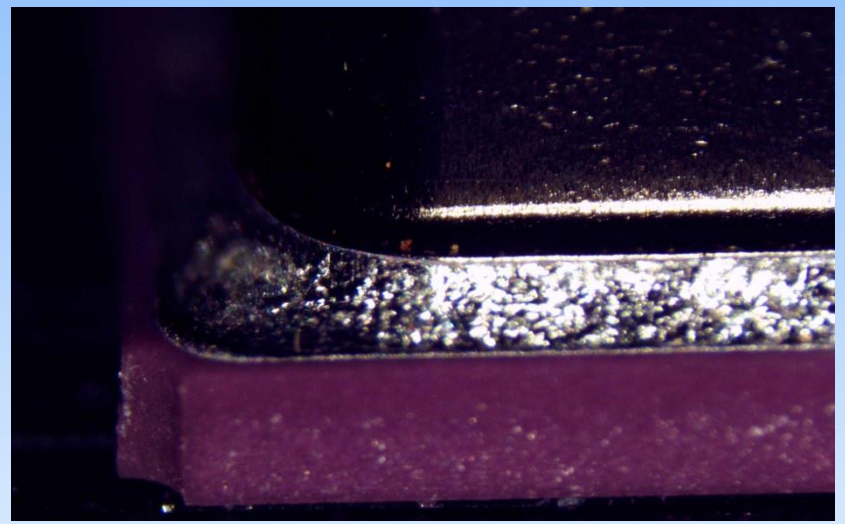
- 30 minutes resin degassing at 150 °C in vacuum
- Formic acid at 200 °C to de-oxidize surfaces, turned off before melting to avoid trapping formates in the hermetic package
- Peak temperature: 250 °C
- Cooling with controlled N_2 flow to avoid pressure variations

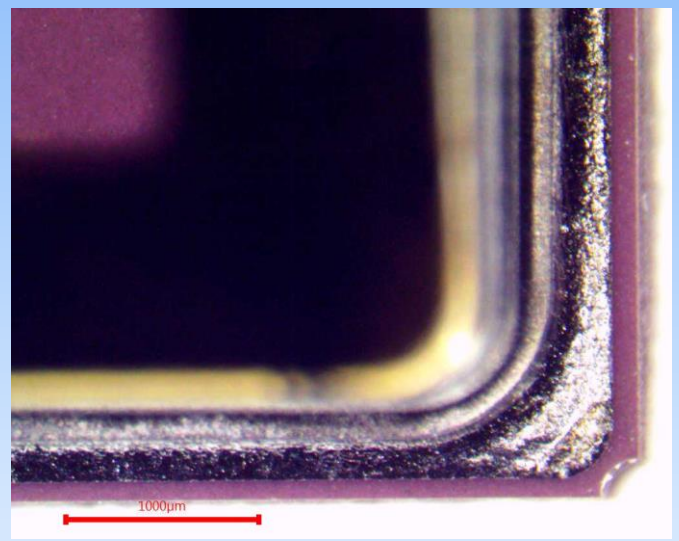


Soldered caps

- Uniform solder fillet, both inside and outside
- Batch processing demonstrated







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Hermeticity: Leak tests

- Hermeticity tested as He leaks according to MIL-STD-883, TM 1014.17, condition A_1 (fine leak) and C_1 (gross leak).
- Reject limit for fine leak test is $3.2*10^{-8}$ atm cm^3/s.
- Typical leak rate is 1 order of magnitude lower

Fine Leak		Gross Leak
Conditions: 2.5h @ 75 psia Reject limit = 3.2E-08 atm·cc/s Volume ≈ 0.08 cc (>0.05, ≤0.1 cc)		Conditions: 2h @ 75 psia
He Leak rate (atm·cc/s)	Result	Result
1.5 E-8	Pass	Pass
4.1 E-9	Pass	Pass
4.1 E-9	Pass	Pass
2.9 E-9	Pass	Pass
7.3 E-9	Pass	Pass

Mirror 1.1 mm

Mirror 3 mm

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Conclusion and outlook

- Hermetic optical package demonstrated
- Platform is industrially scalable
- Test running to confirm application advantages and stability of performances

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