A new generation of Compact Lightweight Absolute Radiometers (CLARA) for space borne TSI observations

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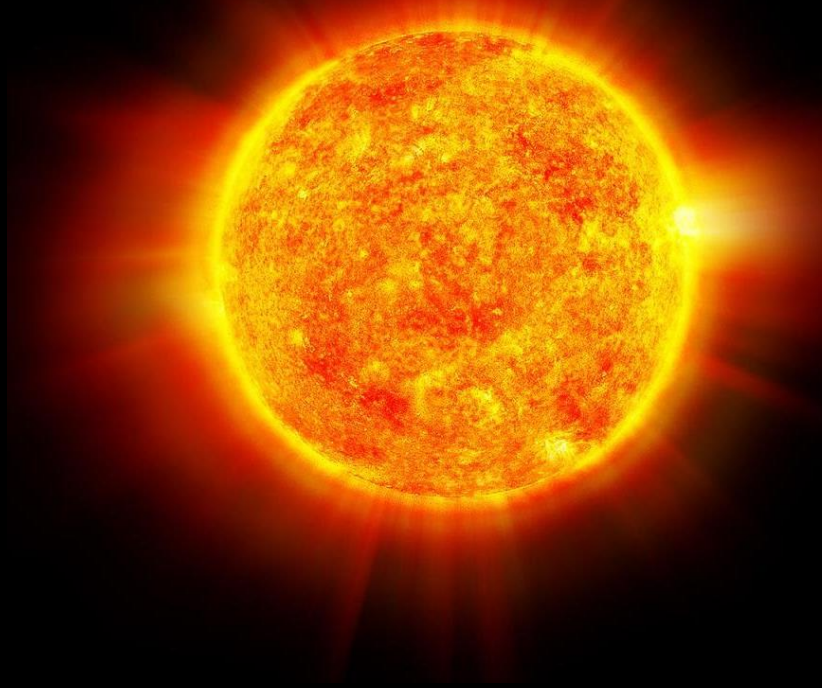
P. Levesque, D. Pfiffner, W. Schmutz



1. Radiometer Design
2. Uncertainties

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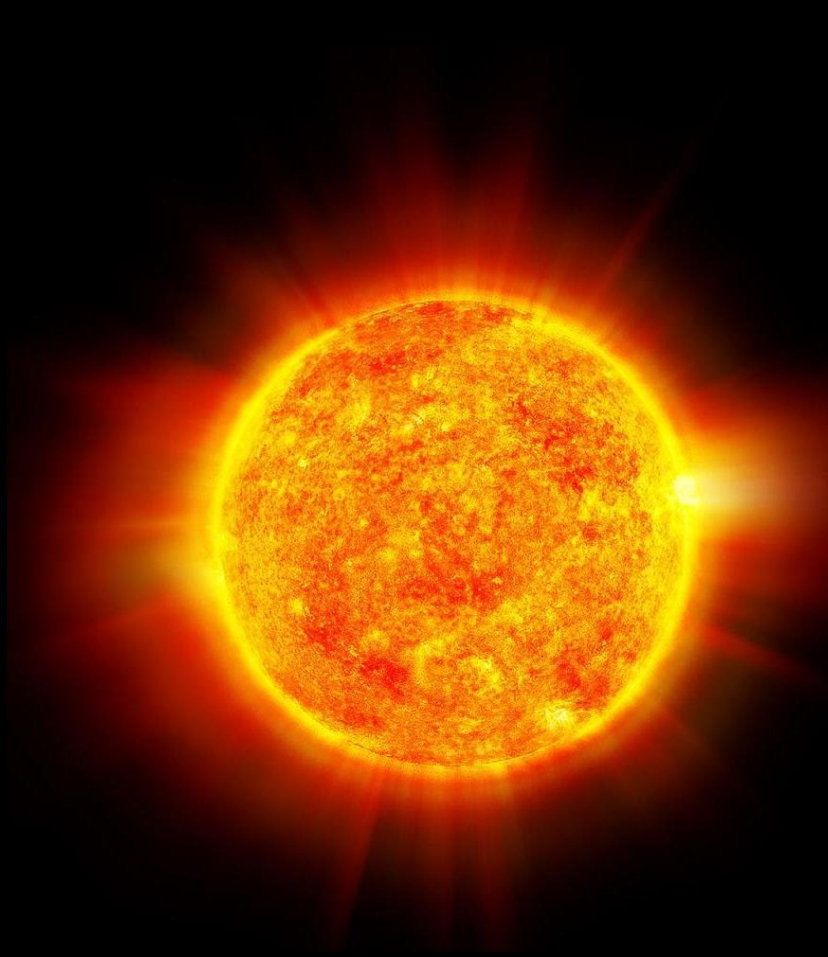
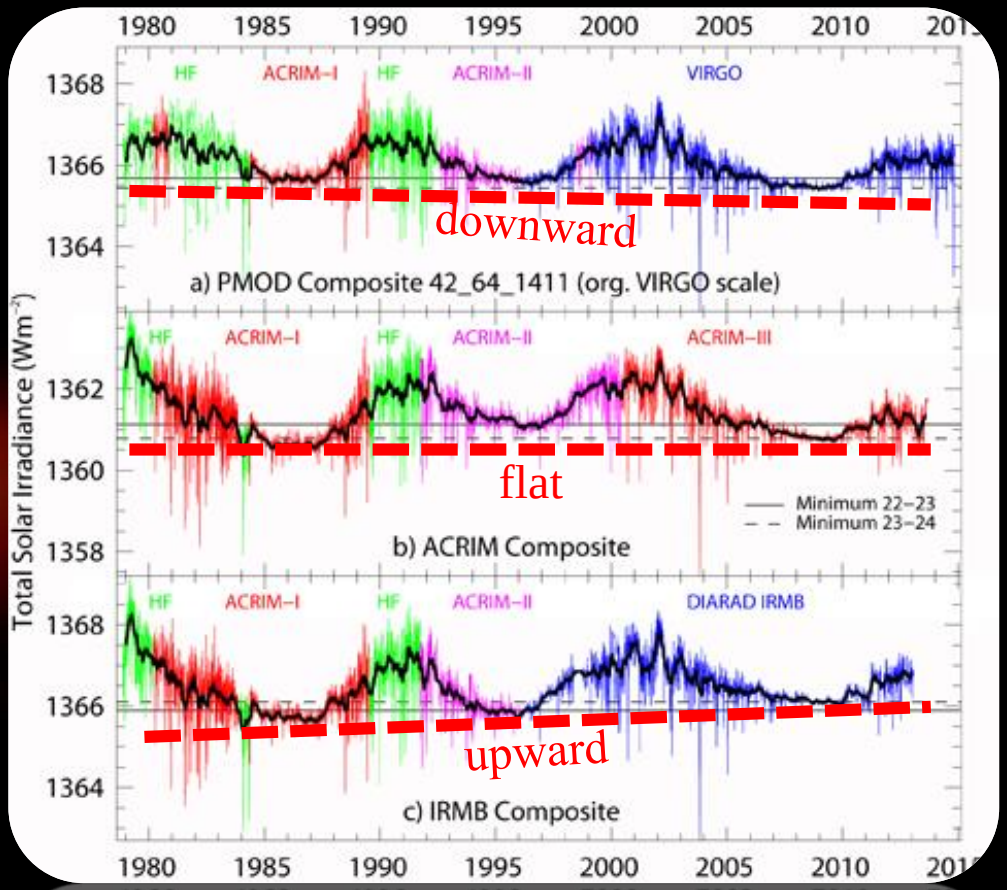
MOTIVATION

Continuous and precise TSI observations

→ Climate Research and Solar Physics





Continuous → inexpensive (small / lightweight) instruments and satellites

Precise → 100 ppm (0.01%) absolute accuracy to detect long term trends

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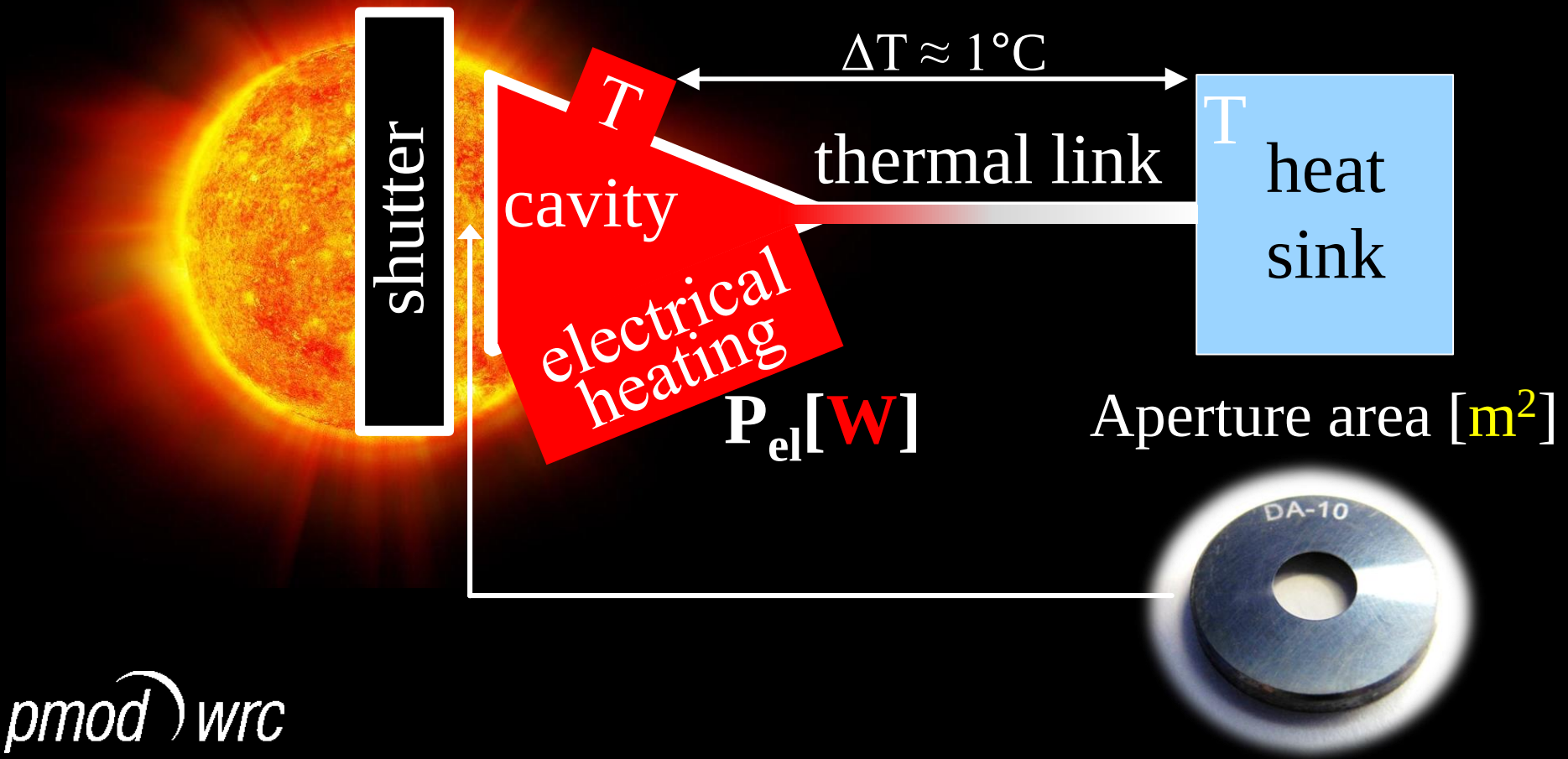
Electrical substitution principle

Solar irradiance [W/m^2]



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CLARA Absolute Radiometer

Norwegian micro satellite NORSAT-1

UTIAS SFL Space Flight Laboratory

* Payloads: - AIS ship tracker
  - CLARA TSI radiometer
  - Langmuir probes
* Launch scheduled for 22nd of December 2016
* Polar low earth orbit (~600 km)
* 3-year nominal mission

Norsk Romsenter NORWEGIAN SPACE CENTRE

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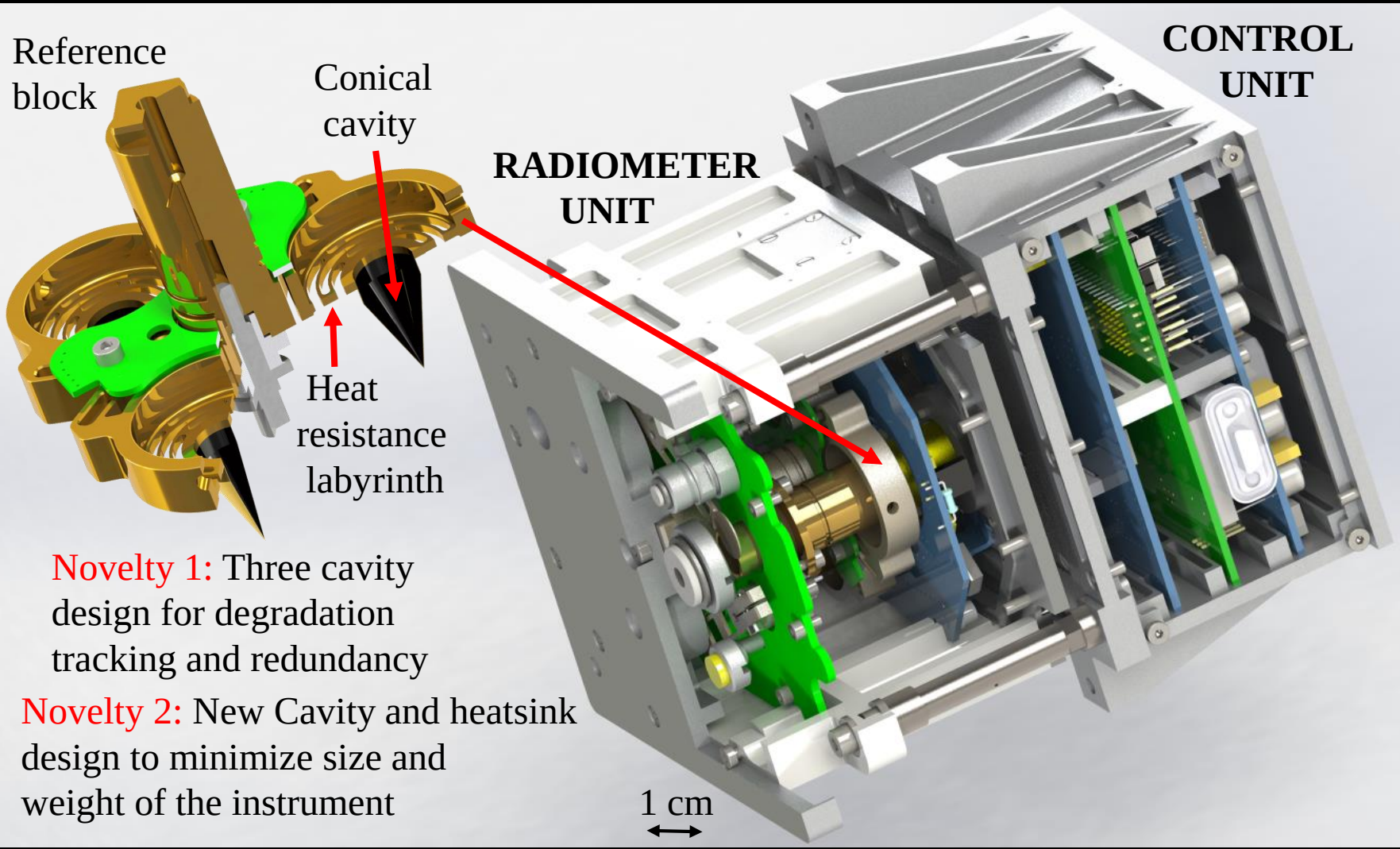
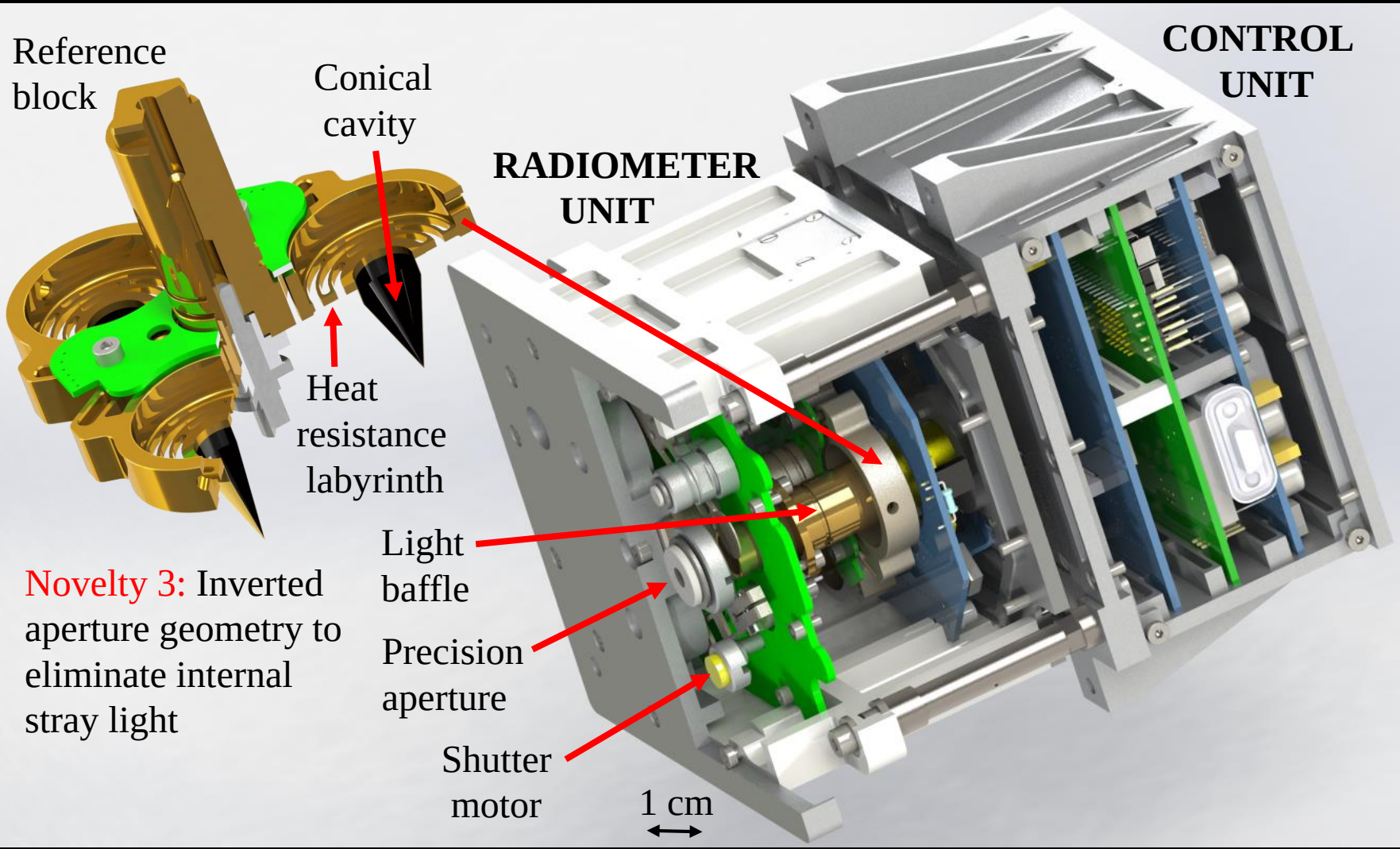
CLARA Design



Novelty 1: Three cavity design for degradation tracking and redundancy

Novelty 2: New Cavity and heatsink design to minimize size and weight of the instrument

CLARA Design



Novelty 3: Inverted aperture geometry to eliminate internal stray light

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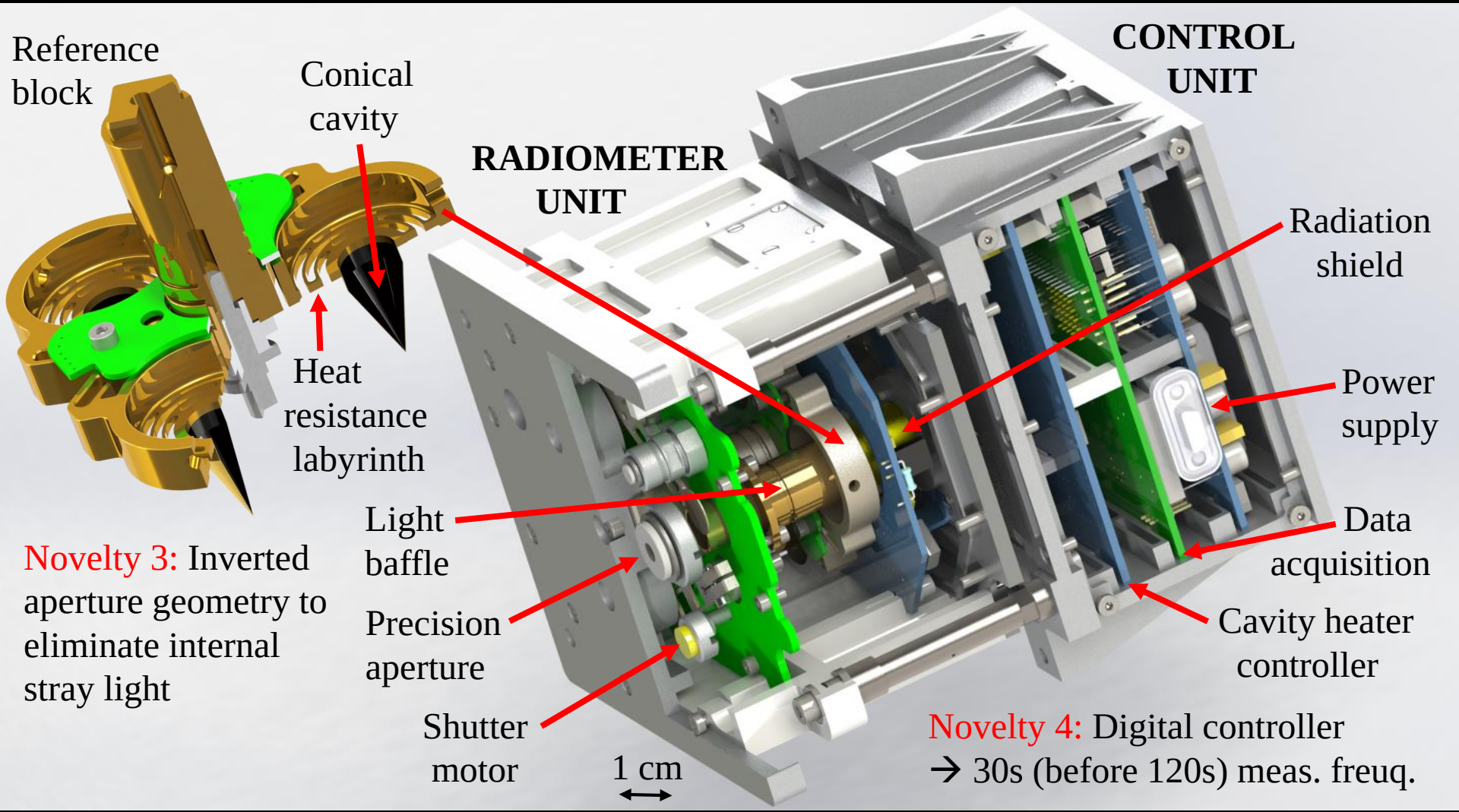
CLARA Design



Novelty 3: Inverted aperture geometry to eliminate internal stray light

Novelty 4: Digital controller
→ 30s (before 120s) meas. freuq.

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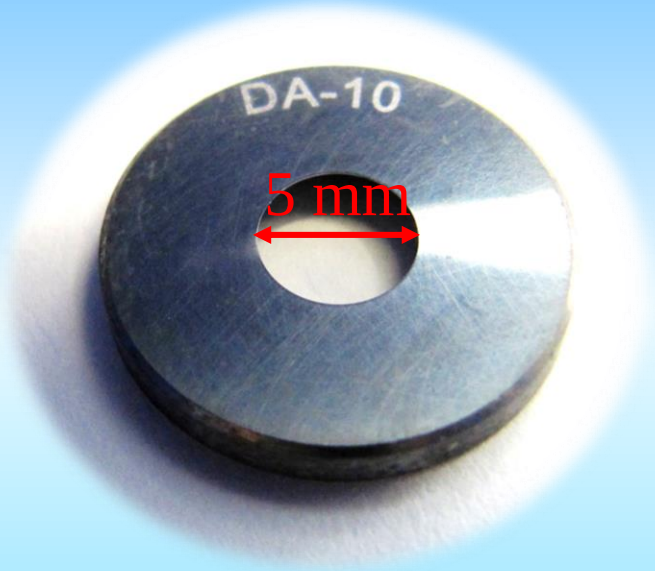
CLARA components/effects uncertainties

1. Aperture area
2. Cavity reflectance
3. Lead heating effect
4. Non-equivalence
5. Diffraction / scattered light
6. Readout electronics

CLARA components/effects uncertainties

1. Aperture area (50 ppm)
2. Cavity reflectance
3. Lead heating effect
4. Non-equivalence
5. Diffraction
6. Readout electronics

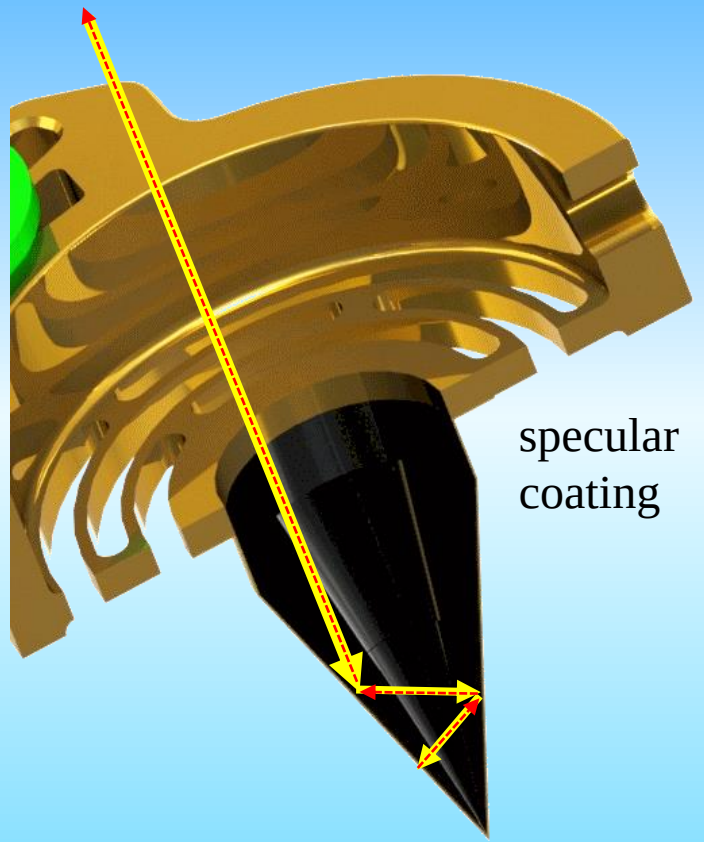
Solar irradiance [W/m^2]



Uncertainty of aperture area measurement = 50 ppm

CLARA components/effects uncertainties

1. Aperture area (50 ppm)
2. Cavity reflectance
3. Lead heating effect
4. Non-equivalence
5. Diffraction
6. Readout electronics



CLARA components/effects uncertainties

1. Aperture area (50 ppm)
2. Cavity reflectance
3. Lead heating effect
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5. Diffraction
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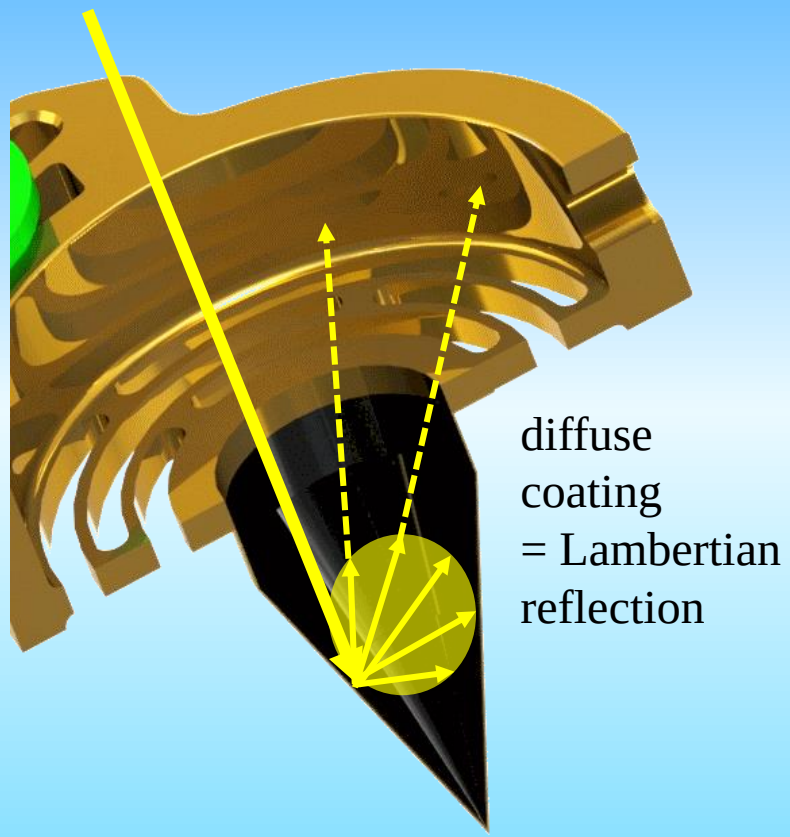
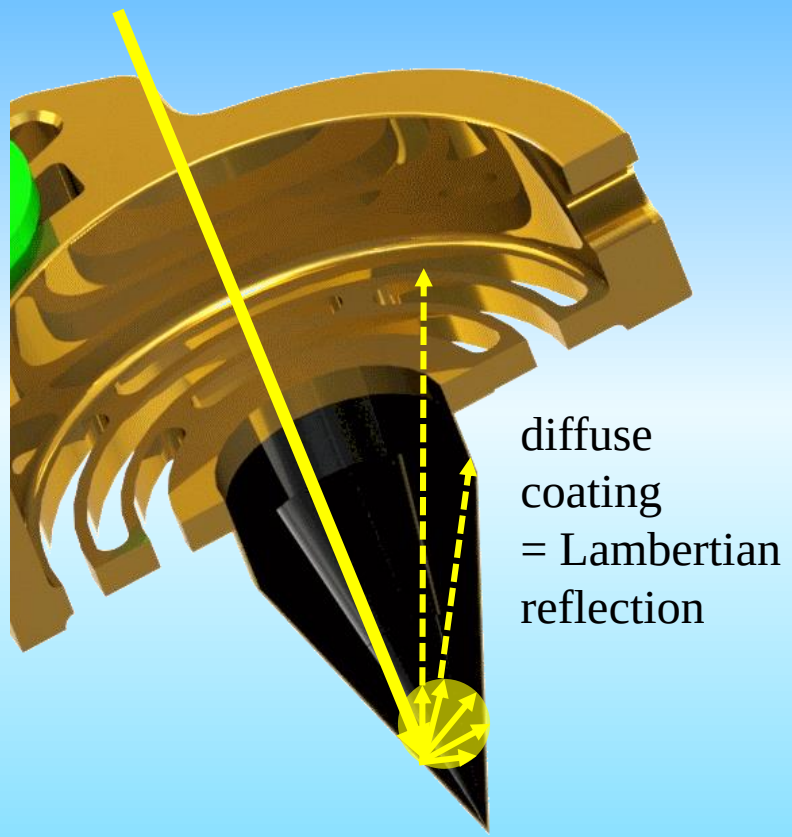


CLARA components/effects uncertainties

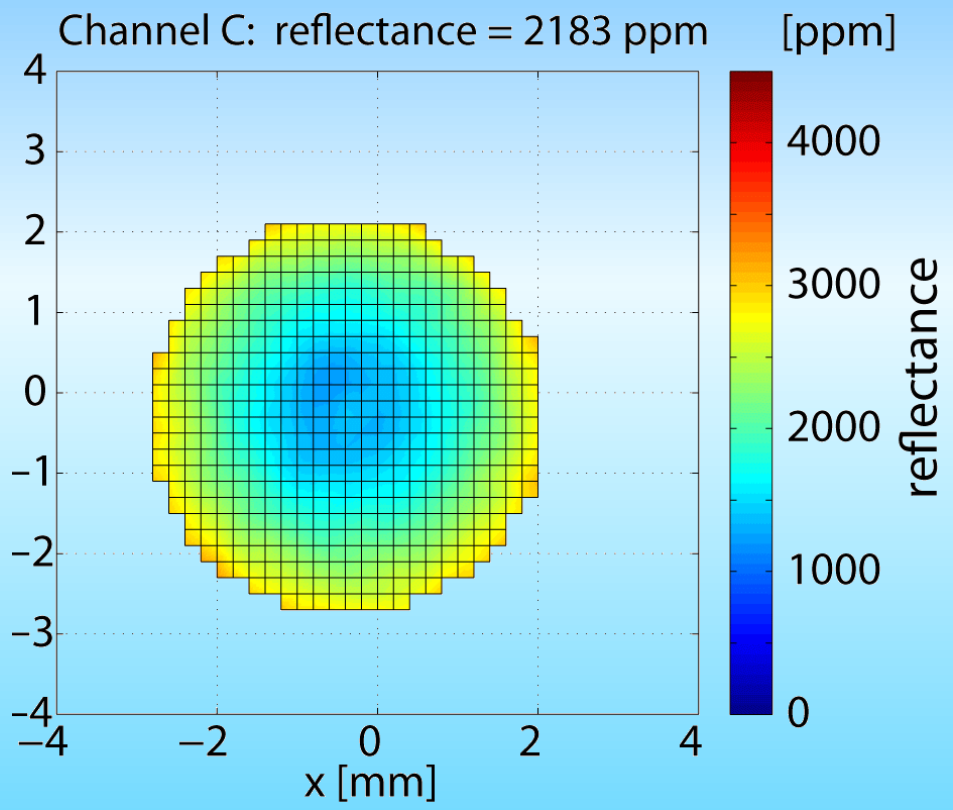
1. Aperture area (50 ppm)
2. Cavity reflectance
3. Lead heating effect
4. Non-equivalence
5. Diffraction
6. Readout electronics



CLARA components/effects uncertainties

1. Aperture area (50 ppm)
2. Cavity reflectance (400 ppm)
3. Lead heating effect
4. Non-equivalence
5. Diffraction
6. Readout electronics

CLARA reflectance map:
(633 nm laser)



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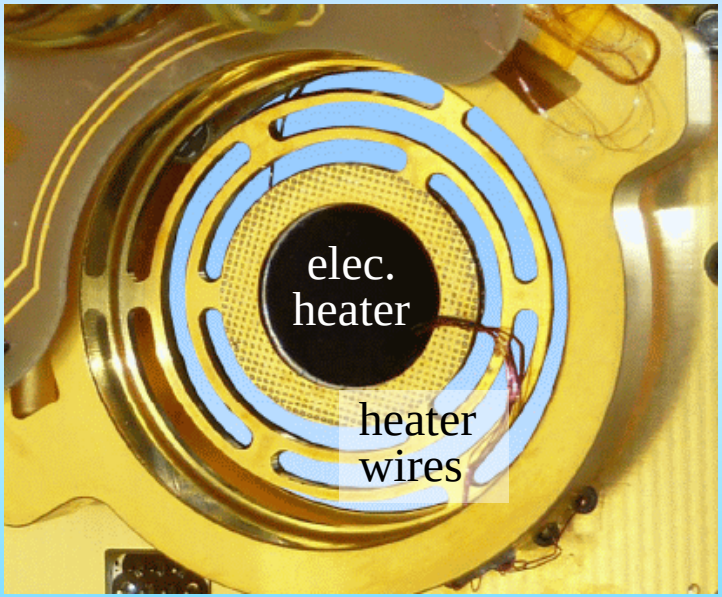
CLARA components/effects uncertainties

1. Aperture area (50 ppm)
2. Cavity reflectance (400 ppm)
3. Lead heating effect (50 ppm)
4. Non-equivalence
5. Diffraction
6. Readout electronics

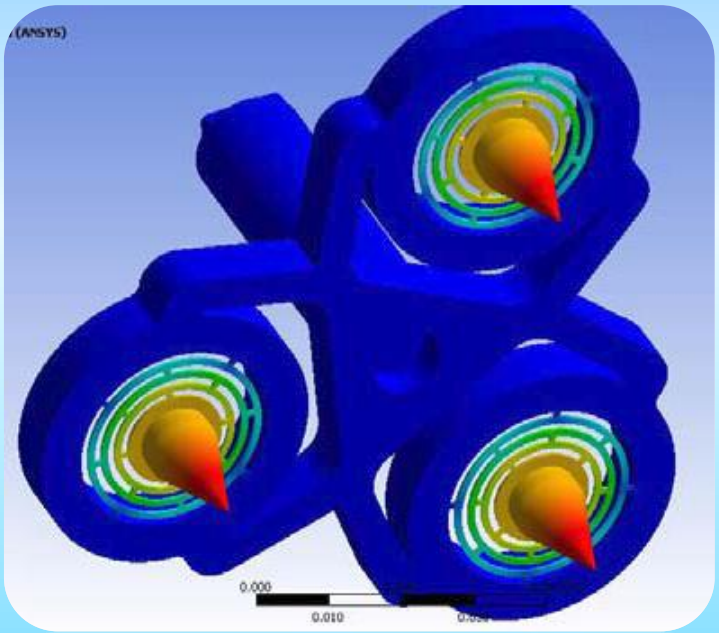
Parasitic heat flow from the cavities to the heatsink through the heater wires which is different for the open and the closed phase.



CLARA components/effects uncertainties

1. Aperture area (50 ppm)
2. Cavity reflectance (400 ppm)
3. Lead heating effect (50 ppm)
4. Non-equivalence (5 ppm)
5. Diffraction
6. Readout electronics

Different temperature distribution within the cavity between radiative and electrical heating



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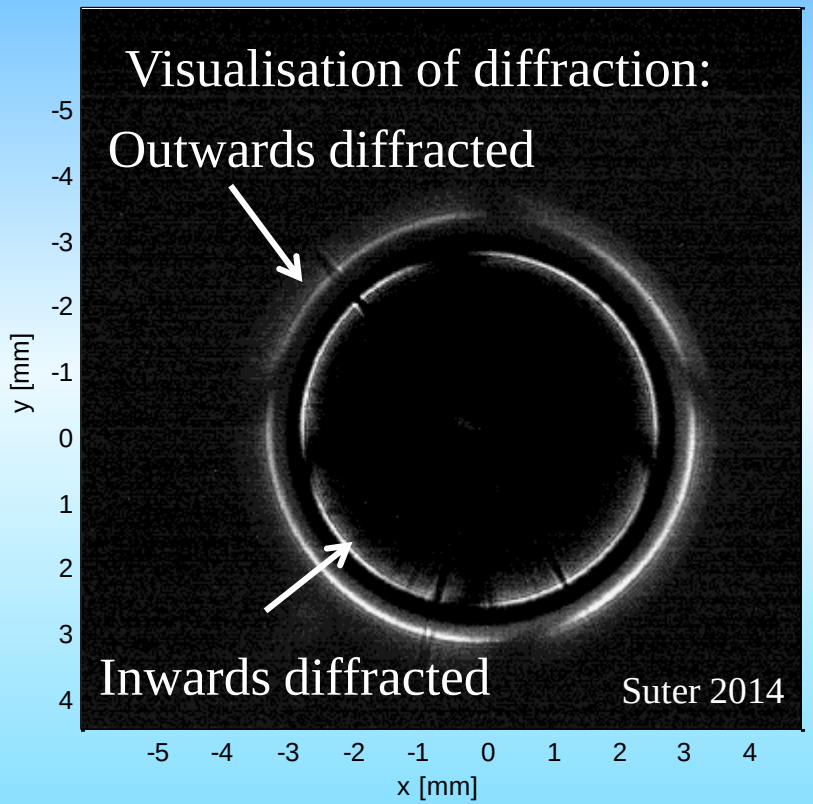
CLARA components/effects uncertainties

1. Aperture area (50 ppm)
2. Cavity reflectance (400 ppm)
3. Lead heating effect (50 ppm)
4. Non-equivalence (5 ppm)
5. Diffraction (30 ppm)
6. Readout electronics

Ligth diffracted at aperture edge



Numerical calculation of diffraction

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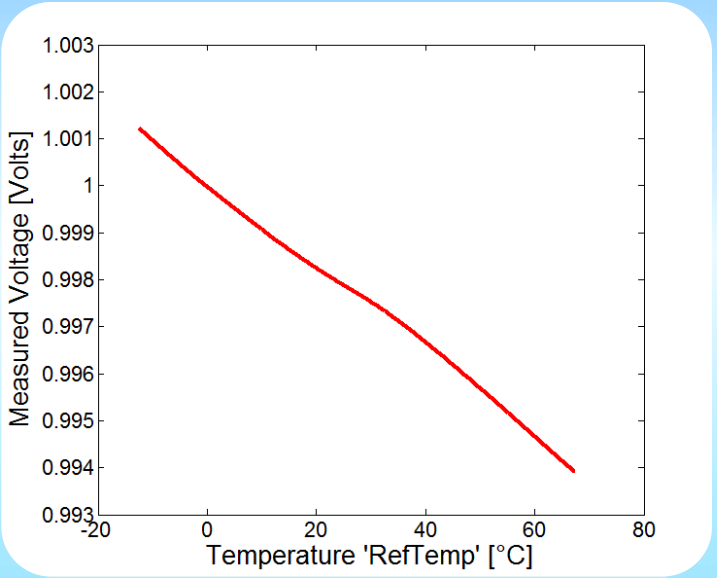
CLARA components/effects uncertainties

1. Aperture area (50 ppm)
2. Cavity reflectance (400 ppm)
3. Lead heating effect (50 ppm)
4. Non-equivalence (5 ppm)
5. Diffraction (30 ppm)
6. Readout electronics (500 ppm)

Temperature dependence of voltage measurement:



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CLARA components/effects uncertainties

1. Aperture area (50 ppm)
2. Cavity reflectance (400 ppm)
3. Lead heating effect (50 ppm)
4. Non-equivalence (5 ppm)
5. Diffraction (30 ppm)
6. Readout electronics (500 ppm)

Total uncertainty of component level characterization (RSS):

≈ 650 ppm

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CLARA components/effects uncertainties

	Goal:
1. Aperture area (50 ppm)	50 ppm
2. Cavity reflectance (400 ppm)	160 ppm
3. Lead heating effect (50 ppm)	30 ppm
4. Non-equivalence (5 ppm)	5 ppm
5. Diffraction (30 ppm)	30 ppm
6. Readout electronics (500 ppm)	70 ppm

Total uncertainty of component level characterization (RSS):

≈ 650 ppm

Goal:
< 200 ppm

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CLARA components/effects uncertainties

	Goal:
1. Aperture area (50 ppm)	50 ppm
2. Cavity reflectance (400 ppm)	160 ppm
3. Lead heating effect (50 ppm)	30 ppm
4. Non-equivalence (5 ppm)	5 ppm
5. Diffraction (30 ppm)	30 ppm
6. Readout electronics (500 ppm)	70 ppm

Total uncertainty of component level characterization (RSS):

≈ 650 ppm

Goal:
< 200 ppm

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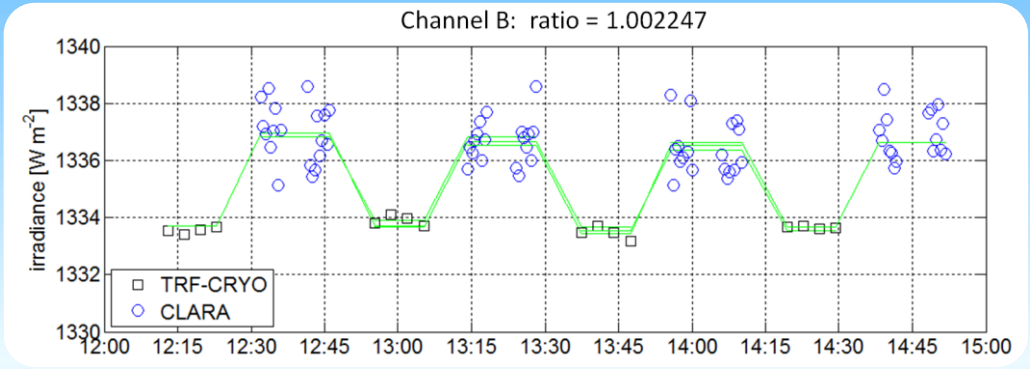
Calibration at TSI Radiometer Facility (TRF)

TRF (Boulder, Colorado)

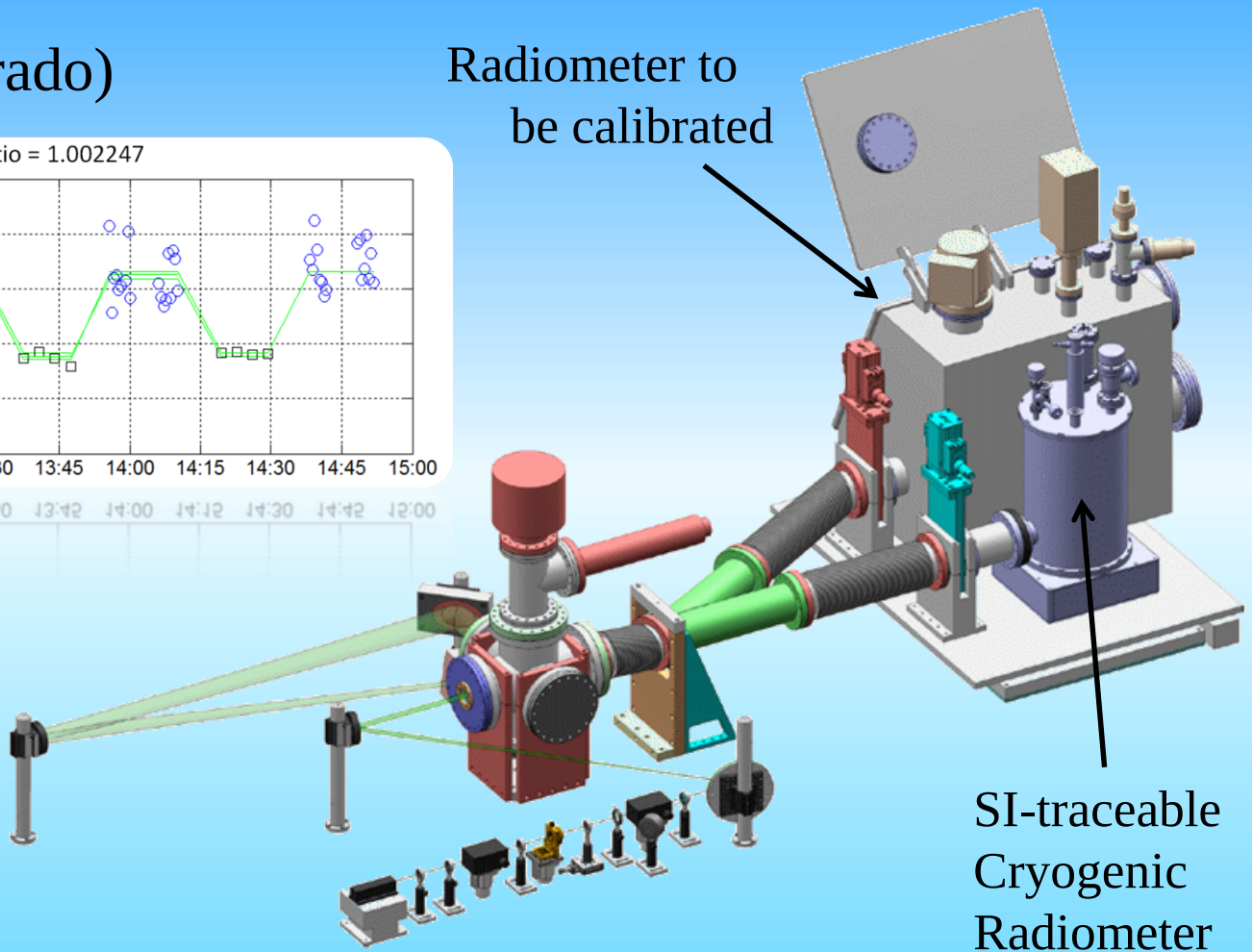


$U_{CLARA} \approx 450$ ppm

With new calibration of CLARA readout electronics

$U_{CLARA} \approx 350$ ppm

Radiometer to be calibrated



SI-traceable Cryogenic Radiometer

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SUMMARY

NEW RADIOMETER DESIGN NOVELTIES:

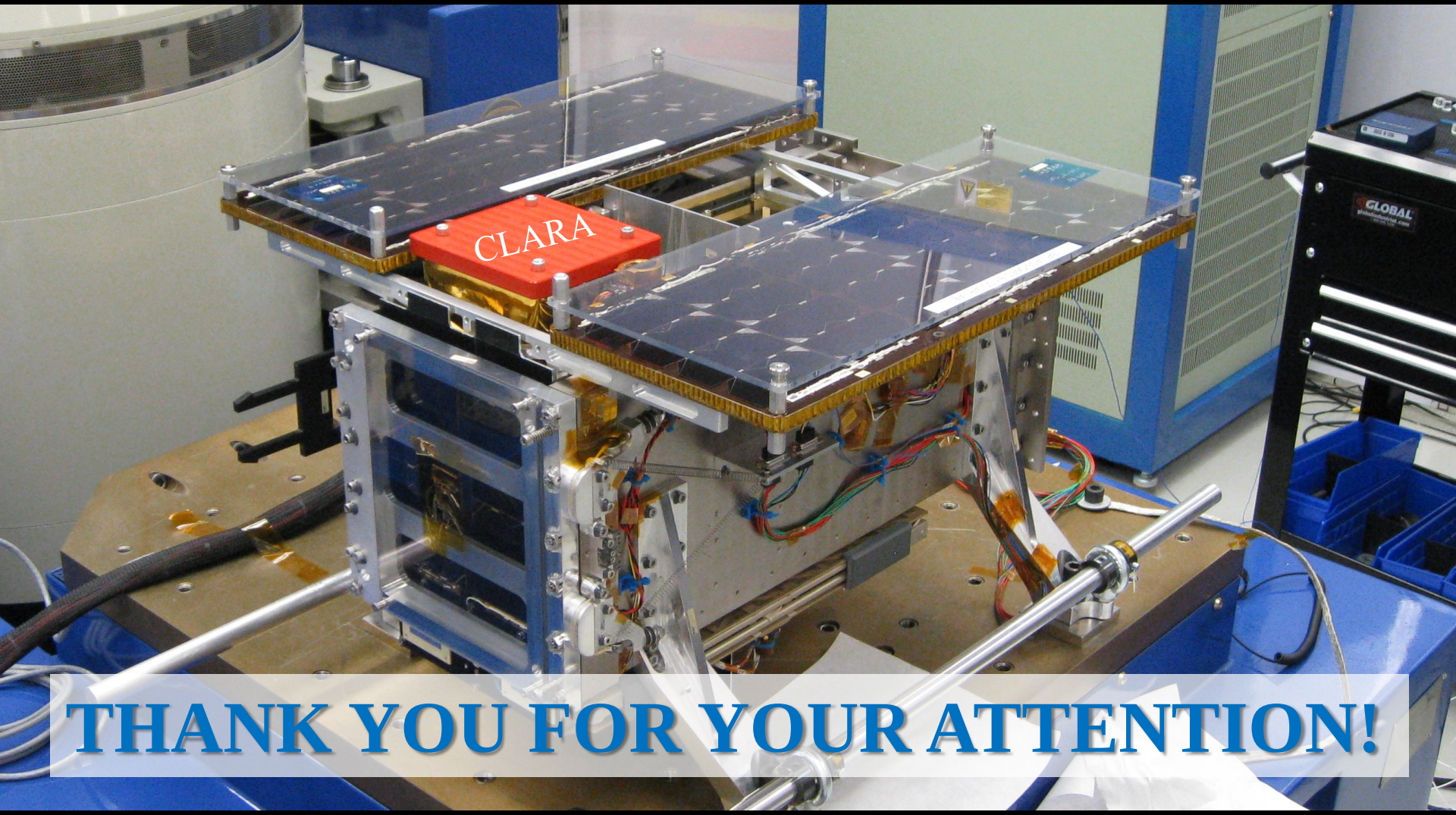
1. Three cavity design for degradation tracking and redundancy
2. Digital controller loop → 30 s measurement frequency
3. Inverted aperture geometry to eliminate internal stray light
4. New cavity and heatsink design to minimize size and weight

CLARA uncertainties:

Currently: ≈ 400 ppm (TRF calibrated)
Possible: ≈ 300 ppm (if recalibration of readout electronics)

NORSAT-1 launch scheduled for 22nd December 2016

CLARA on NORSAT-1



THANK YOU FOR YOUR ATTENTION!

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