FAIRE LA LUMIÈRE
SHEDDING LIGHT

ACTIVE TeraHertz Imaging : SOURCE CHALLENGE

André Fougères ; VP Innovation & Technology

EPIC World Photonics Technology Summit
Berlin, August 2019

Outline

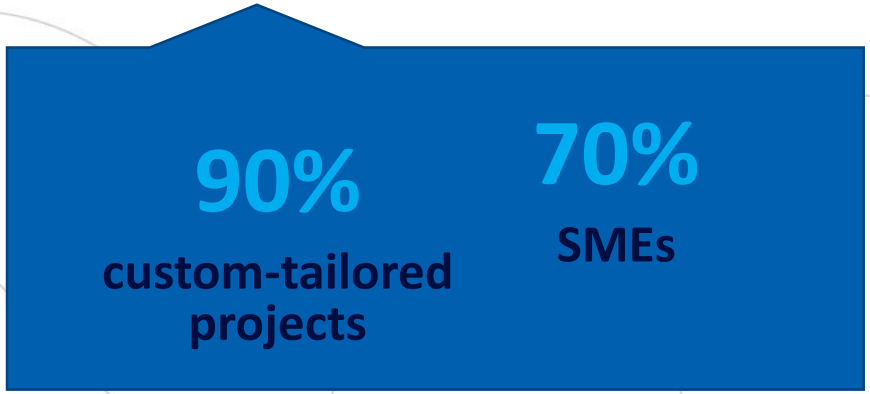
- About INO
- About Active TeraHertz (THz) Imaging
- The Source Challenge

About Us

- INO is a private institute for translational **applied research** (RTO)
- **Founded in 1988**
- **> 200** employees
- Annual budget > **$35 M**
- **ISO 9001** and **13485**
- Offices in Québec (HQ), Montréal, and Hamilton

What we do

- Complete range of services in **optics**, **photonics,** and **vision**
  - Integrated approach to reduce development time, iterations, costs, and risks
  - Studies, consulting services, prototyping, product developments, pilot productions, technology transfers, and spin-offs
- We act as a bridge between industries and the academic world
- Customers across all **categories**, in Canada and around the world
- Revenues: 50% from **customer contracts** and 50% from **government contracts**



In 30 years…

292
Patents

34
Spin-offs

More than
6,500
solutions

51,8 %
Average self-financing rate

74
Technological transfers

* As of March 31, 2019

Creator of 2000+ jobs

RAYSECUR™
SAFE ACCESSIBLE DETECTION

LeddarTech

Swiftsure Spatial Systems

Pavemetrics

UMANX™

TeraXion

PYROPHOTONICS
THE SHAPE OF LIGHT TO COME

LynX Inspection

CorActive

OPTEL VISION

OPTOSECURITY

neoptix

P&P Optica

FLYSCAN

AEREX AVIONIQUE

opSens

neks

Optiwave

FISO

OBZERV

doric
doric lenses

Our business units

City, Infrastructure, and Mobility

Defense, Security, and Aerospace

Advanced Manufacturing

Energy, Resources, Environment

Biomedtech

Total hip arthroplasty

intellijoint surgical

Provides real-time, intraoperative implant measurements for:

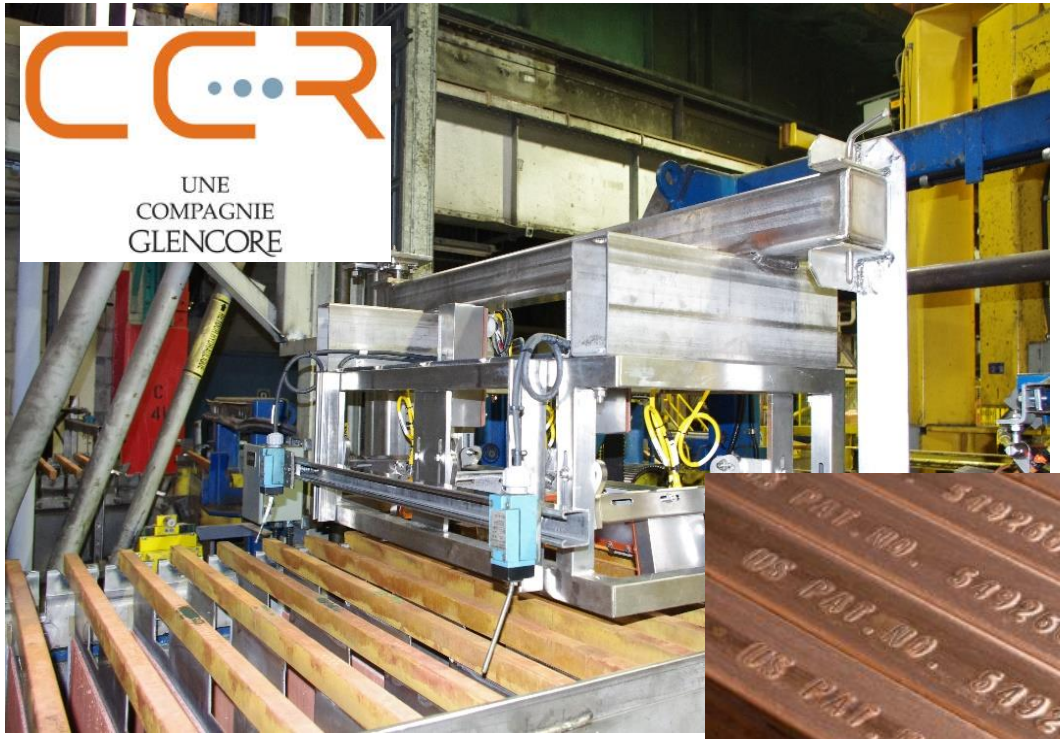
Cup position
Leg length
and offset of hip center of rotation

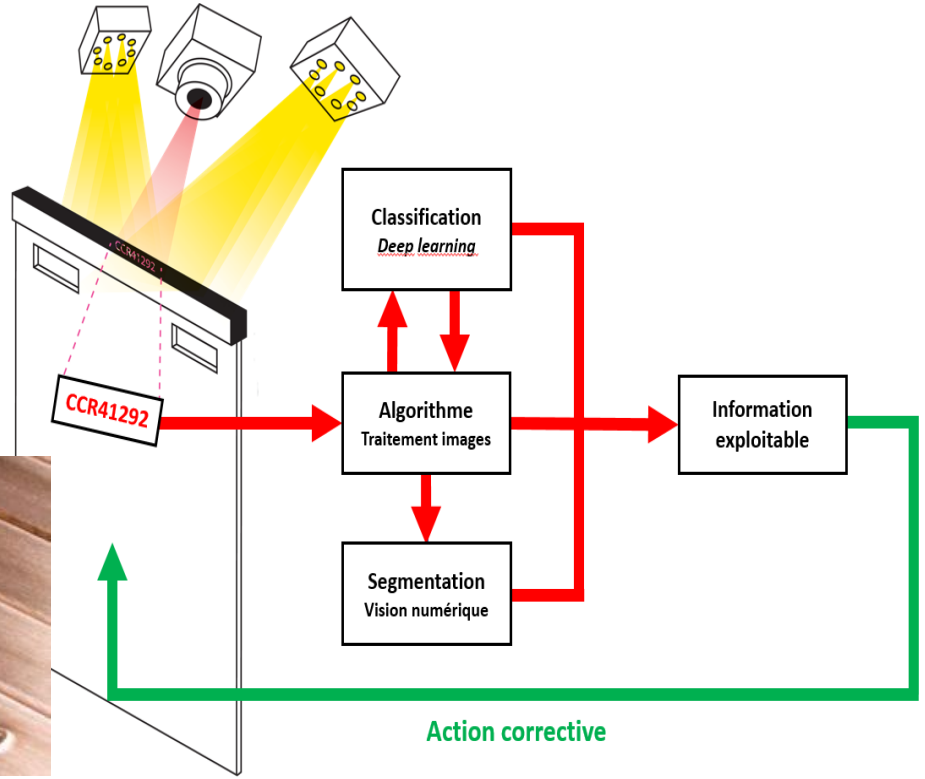
Armen Bakirtzian, CEO, Director and Co-founder; Andre Hladio, Chief Technology Officer and Co-founder; Richard Fanson, Chief Science Officer, Director and Co-founder.

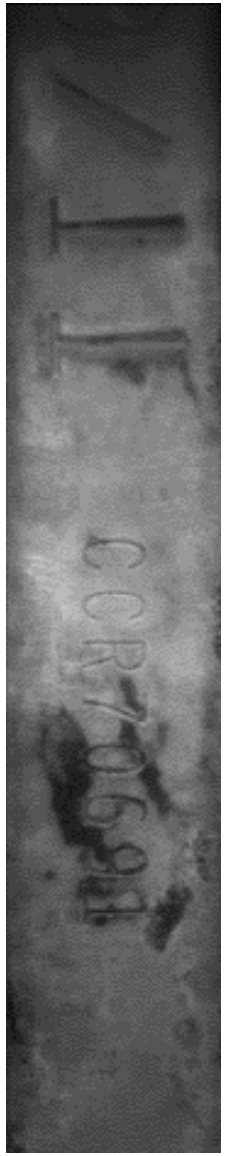
Copper refining by electrolytic plating

Automatic optical character recognition system

- Based on an Active Vision system + Deep Learning algorithm
- Reading success rate of 98.1% ; 85 000 readings per week







Mushroom harvesting

Determination of the degree of ripeness of mushrooms and automated designation

- Based on a hyperspectral camera system, deep learning and a laser « mushroom designator »

Imaging Microspectrometer

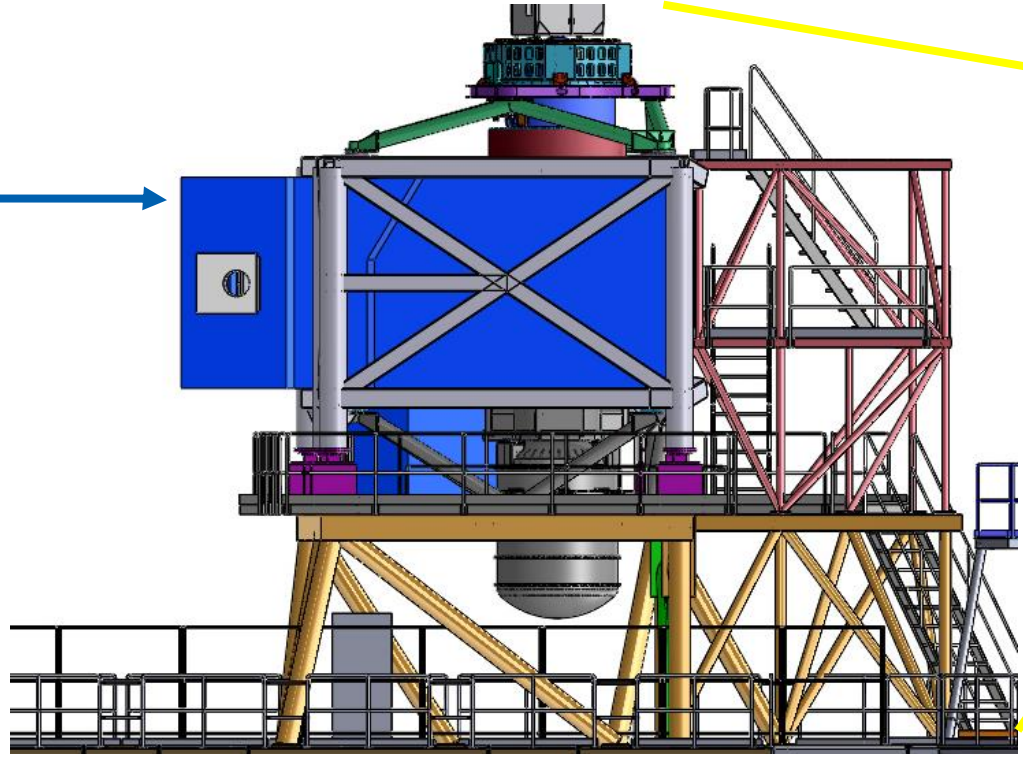
vineland
RESEARCH & INNOVATION CENTRE

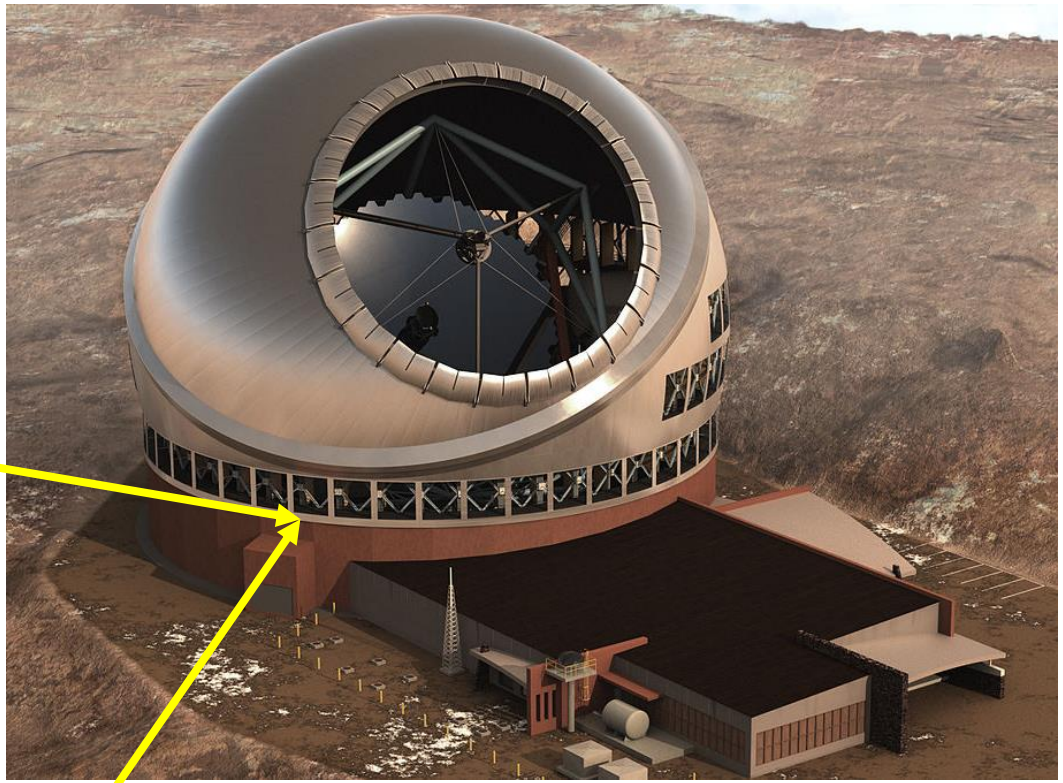
Adaptive Optics for the 30m-telescope (TMT)

NFIRAOS

(Narrow-field infrared adaptive optics system)

Adaptive optics corrects the signal for aberrations induced by atmospheric turbulences.

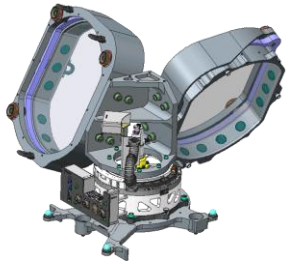


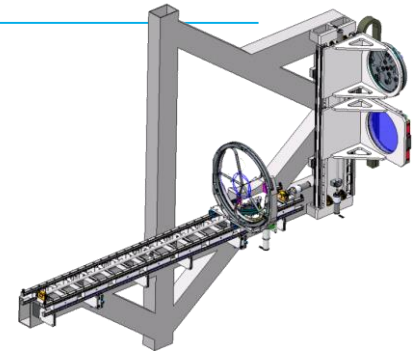


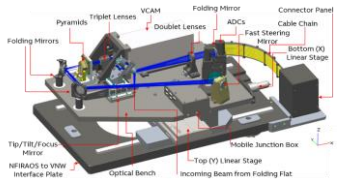
Canada NRC·CNRC

TMT THIRTY METER TELESCOPE

NFIRAOS – Opto/mecanics schematics







Flow cytometer for … anywhere

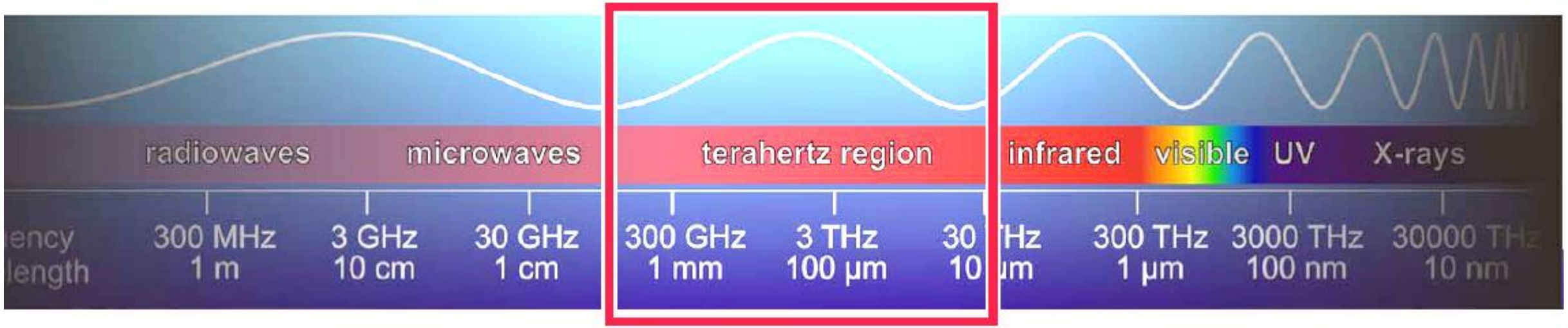
Chris Hadfield introduces Microflow, a Canadian technology that can be used to analyze blood samples anywhere, in just a few minutes.

Credits: Canadian Space Agency, NASA

TeraHertz

THz Waves

THz spectral band



Spectral values

Frequency: 0.1 – 10 THz

Wavelength: 3 mm – 30 µm

Energy: 0.41 – 41 meV

Color Temperature: 1 – 100 K

Wavenumber: 3.3 – 33 cm^{-1}

Benefits

Longer wavelength / deeper penetration

See-through camouflage and objects

106X less energy than X-rays

Non-ionizing unlike X-rays

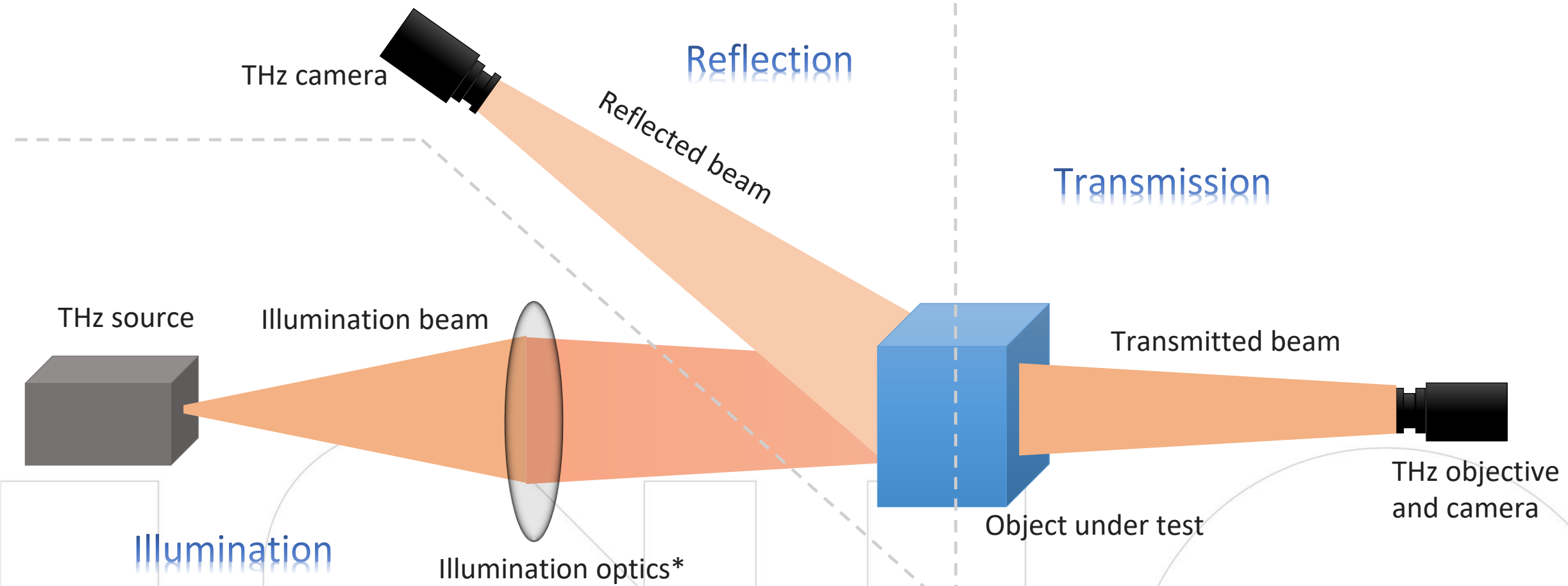
Presence of atmospheric transmission windows

Interactions

IR: vibrational states

THz: rotational states

Active THz Imaging Overview



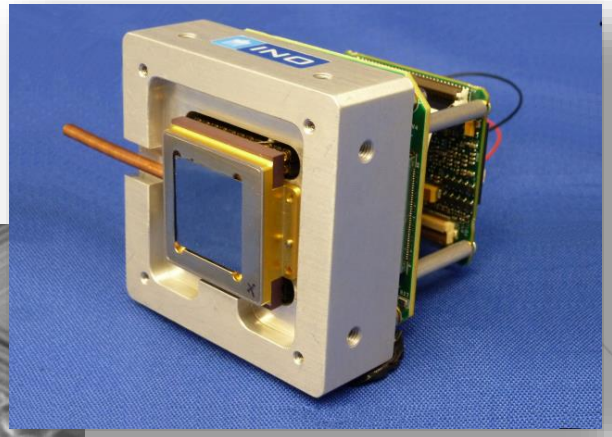
*Illumination optics may be a series of lenses or mirrors depending on the specific imaging requirements

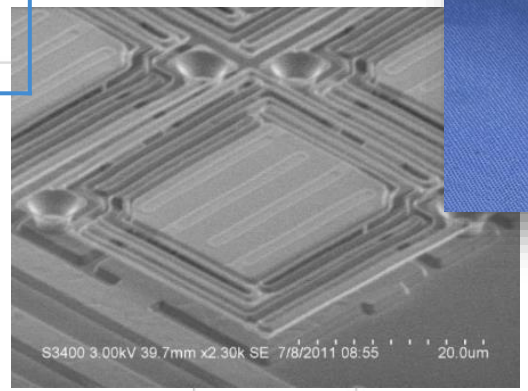
MICROXCAM-384i-THz

- Based on **uncooled** bolometer technology
- Optimized pixel design, absorbing layer, packaging, electronics and optics for 94 GHz – 5 THz range

(61 x 61 x 65 mm^3)

Pixel count	384x288 pixels
Pixel pitch	35 µm
Response time	11 ms
NEP	59 pW (at 70 µm wavelength) 41 pW (at 118.8 µm wavelength) 80 pW (at 214 µm wavelength) 88 pW (at 662 µm wavelength)





The camera "in action":
INO See-through imaging (Youtube)

THz Imaging Applications

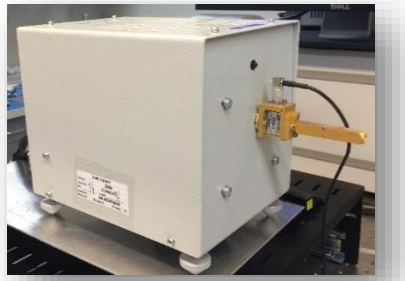
- Advanced Manufacturing
  - Packaged Goods Inspection
  - Foam/Plastic Inspection
- Security
  - Mail Inspection
  - Body Scanning
- Military
  - Explosives Detection
  - Degraded Visual Environment
  - Thru-Wall Detection
- City, Infrastructure & Mobility
  - Wall Scanner
  - Cable/Pipe Inspection
  - Tile Inspection
- Biomedtech
  - Skin Cancer/Rash/Burn Monitoring
  - Dental Inspection
  - Pill Box Inspection

THz/Millimeter-Wave Sources

IMPATT Diodes

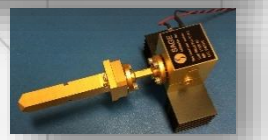
- Compact
- Single wavelength (fixed)
- Can be combined with frequency multipliers
- Maximum output power 100 mW

Backward Wave Oscillators



- Bulky
- Multi-wavelength
- Can be combined with frequency multipliers
- Maximum output power 100 mW

Schottky & GUNN Diodes



- Compact
- Single wavelength
- Can be combined with frequency multipliers
- Maximum output power 100 mW

Klystrons

- High Power
- Large Power Supply
- Expensive
- Maximum output power 10 W

RaySecur: an INO THz Spin-off

- Mail screening based on INO's THz imaging technology

RAYSECUR™

https://raysecur.com/mailscreening-device/

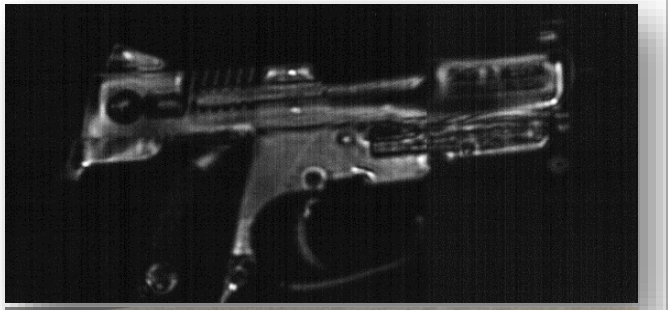
See items inside package in real-time.

Liquid and powder detection are easily detected and confirmed.

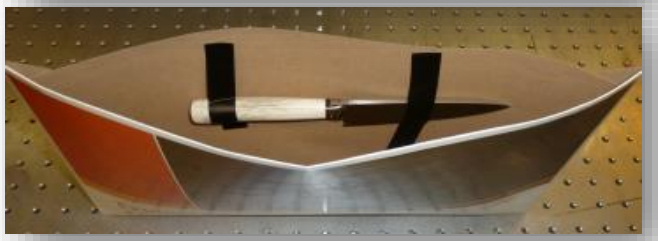
* Flat-top uniform illumination based on freeform optics

THz Imaging Examples

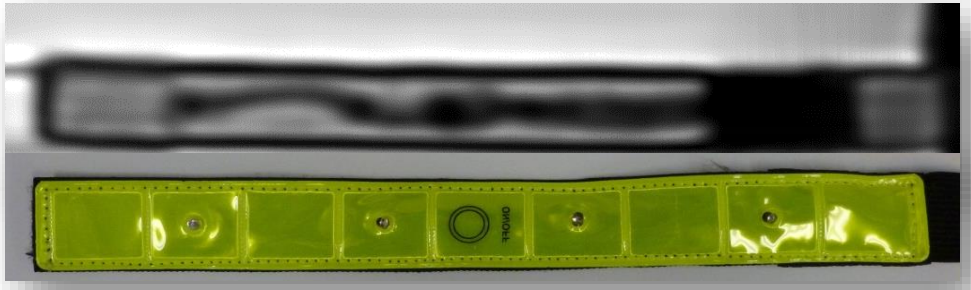
Reflection
@660 µm/450 GHz



Reflection
@118 µm/2.54 THz



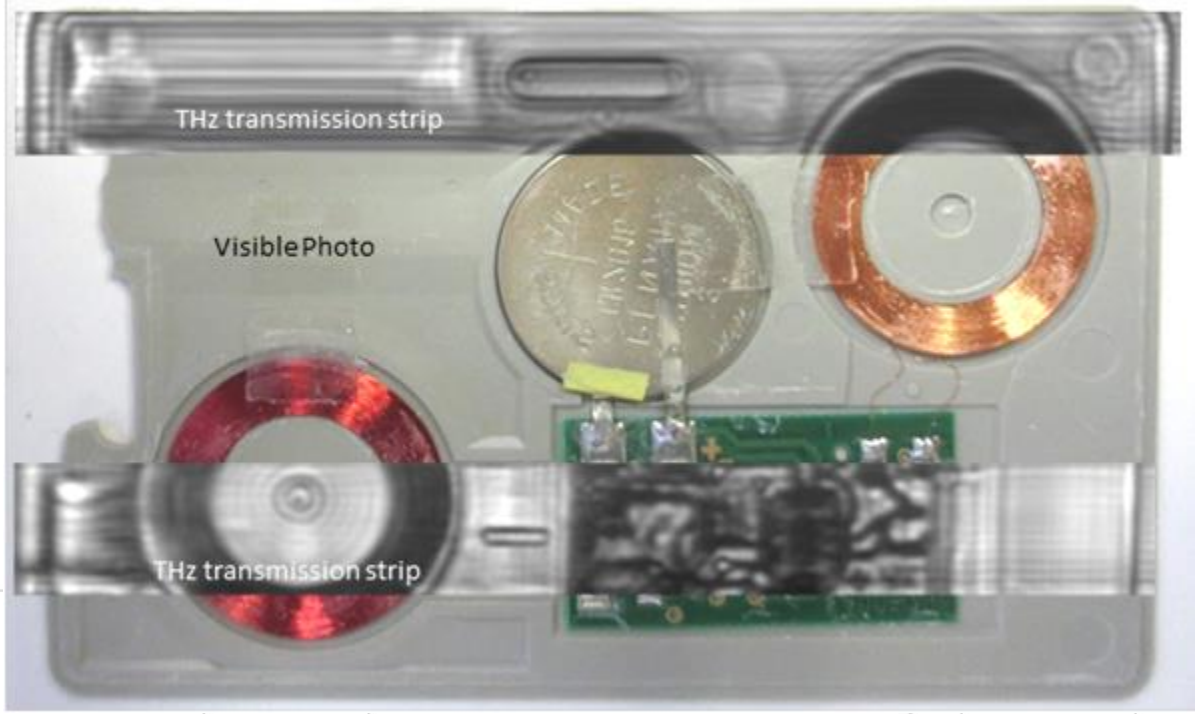
Transmission
@ 432 µm/694 GHz



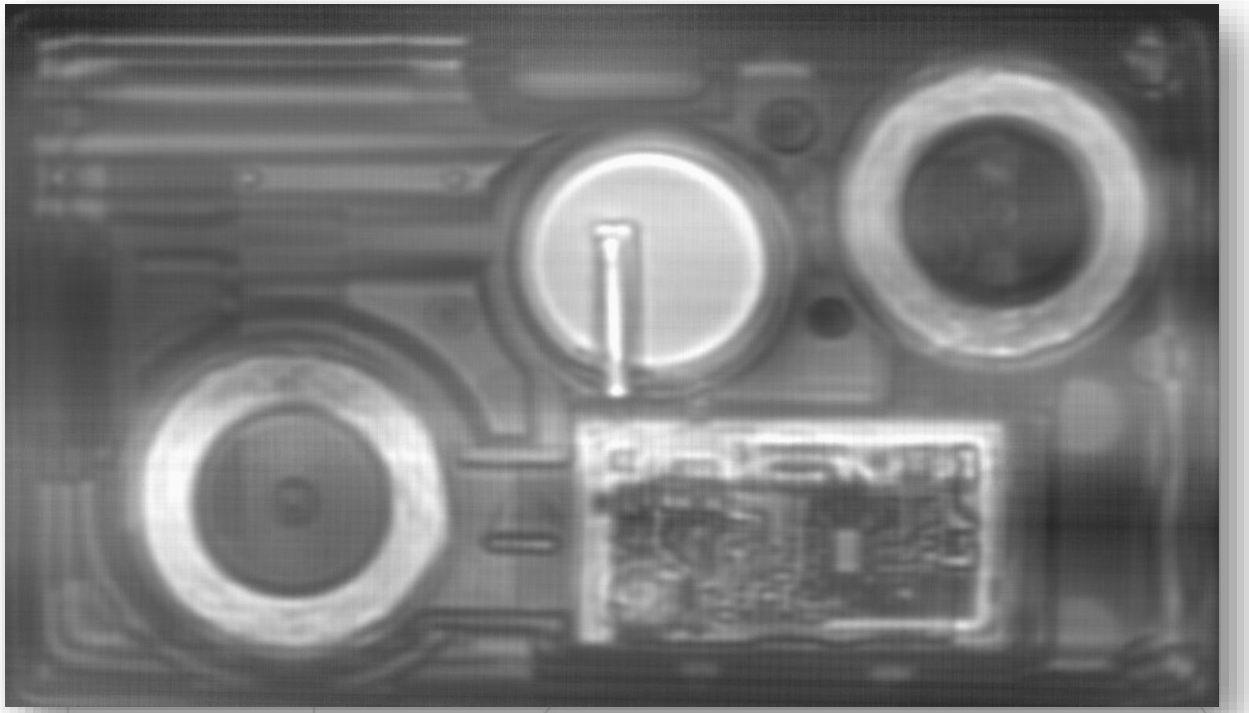
Transmission
@750 µm/400 GHz

Mosaic of scanned images

- Plastic magnetic security card
- Single image size: 13.5 mm x 10 mm
- Horizontal and vertical scans were taken over sealed card then assembled



Visible image of opened card with two horizontal THz transmission strips overlayed



Mosaic of THz image strips taken of sealed card

THz Source *Current* Requirements

- Compact, Low Cost (CLC)
  - **Application**: Handheld, MailSecur, *NDT, Quality Assurance, Biomed*
  - **Dimensions**: 5 cm x 5 cm x 10 cm
  - **Cost**: 7-10 k$ (100+ units per year)
  - **Frequency**: 282 GHz
    - Matched to FSS
  - **Bandwidth**: 5-20 GHz (TBC)
  - **Output Power**: 20 – 40 mW
  - **Lifetime: >**3 years
- High Power (HP)
  - **Application**: HTPS, *Infrastructure Monitoring*
  - **Dimensions**:
    - Source head <20 cm^3
    - Power & Cooling Unit <1 m^3
  - **Cost**: < 75-100 k$
  - **Frequency**: within 260 – 300 GHz
  - **Bandwidth**: 5-10 GHz (TBC)
  - **Output Power**: 1 - 2 W (TBD)
  - **Lifetime**: >3 years

THz Source *Short Term* Requirements

- Compact, Low Cost (CLC)
  - **Application**: Handheld, MailSecur, *NDT, Quality Assurance, Biomed*
  - **Dimensions**: 5 cm x 5 cm x 10 cm
  - **Cost**: 8-12 k$ (100+ units per year)
  - **Frequency**: 520 GHz
    - Matched to FSS
  - **Bandwidth**: 5-20 GHz (TBC)
  - **Output Power**: 30 – 60 mW
  - **Lifetime: >**3 years
- High Power (HP)
  - **Application**: HTPS, *Infrastructure Monitoring*
  - **Dimensions**:
    - Source head <20 cm^3
    - Power & Cooling Unit <1 m^3
  - **Cost**: < 75-100 k$
  - **Frequency**: within 260 – 300 GHz
  - **Bandwidth**: 5-10 GHz (TBC)
  - **Output Power**: 1 - 2 W (TBD)
  - **Lifetime**: >3 years

THz Source *Mid-Term* Requirements

- Compact, Low Cost (CLC)
  - **Application**: Handheld, MailSecur, *NDT, Quality Assurance, Biomed*
  - **Dimensions**: 5 cm x 5 cm x 10 cm
  - **Cost**: 5-7 k$ (100+ units per year)
  - **Frequency**: 700-750 GHz
    - Matched to FSS
  - **Bandwidth**: 10-20 GHz (TBC)
  - **Output Power**: >150 mW
  - **Lifetime:** >5 years
- High Power (HP)
  - **Application**: HTPS, *Infrastructure Monitoring*
  - **Dimensions**:
    - Source head <10 cm^3
    - Power & Cooling Unit <0.5 m^3
  - **Cost**: <60 k$
  - **Frequency**: 400-500 GHz
    - TBD if matched to FSS
  - **Bandwidth**: 10-20 GHz (TBC)
  - **Output Power**: 1 - 5 W (TBD)
  - **Lifetime**: >5 years

Help! We are looking for:

- Supplier with existing product …
- Supplier willing to invest in adapting/scaling existing product
- Development partner owning adaptable/scalable base technology
- Supplier of THz source technology (i.e. tech transfer)
- Else

- All of the above

One last thing: ***incoherent*** THz source would be an asset

What INO can do for you :

- Custom specialty optical fiber design and manufacturing
- MEMs foundry services
- Vision system development (with Deep Learning algos)
- Optical/Mechanical Design
- Sensors
- Else

- Technology Transfers

  - Lens centering (teaser *https://www.youtube.com/watch?v=HO0S3-Oejzg)*

Thank you
for your attention

This presentation was presented at EPIC World Photonics Technology Summit 2019

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