Activities at COPL

University-Based Centre
For Training and Research in Optics & Photonics (COPL)

23 faculty-led research teams / 150 graduate students
12 research scientists / 10 technicians

RESEARCH AXES:

- **Optical Communications**
- **Lasers & Ultrafast Phenomena**
- **Biophotonics**
- **Fiberoptics & Integrated Optics**
- **Photonic Materials**
- **Optical Instrumentation & Engineering**

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Shaping light
one ray at a time

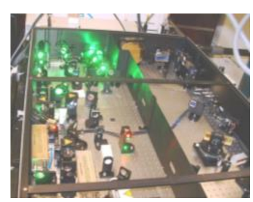
World-Class Facilities Unique in Canada

6,900 m^2 of lab space
Class 10,000 to 1000 clean room environment
Control over vibrations, humidity, temperature, dust

2 fibre-optic drawing towers

Thin film deposition facilities

Nanoscale characterization and etching system



Femtosecond laser chains

Glass synthesis and purification facilities

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Shaping light
one ray at a time

Fabrication, assembly and optical testing laboratory

Precitech Nanoform 250
Ultra precision freeform CNC machine designed for single point diamond turning and freeform milling and grinding.

ZEEKO IRP 200
7-axis CNC optical polishing machine for producing ultra-precise surfaces on a variety of optical materials and surface forms. Used for post-polishing of components made on the Precitech Nanoform 250.

ESDI H2000 et Zygo interferometers
Metrology instrument for non-contact precision measurement of flat or spherical surfaces.

Talysurf PGI Freeform Surface Profiler
Metrology instrument for precision form measurement of 3D form of shallow and steep aspherical lenses and molds from < 2mm and up to 300mm diameter.

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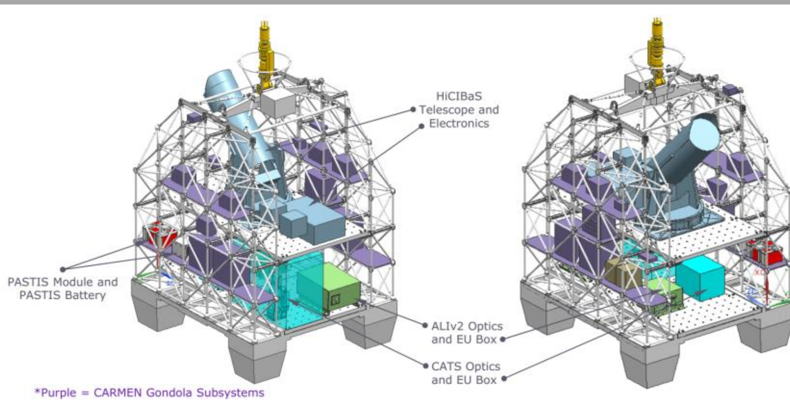
Shaping light one ray at a time

HiCIBaS



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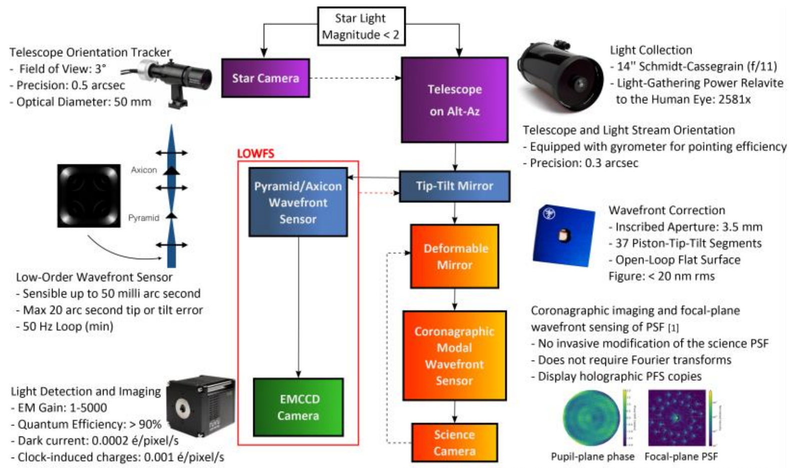
System Block Diagram

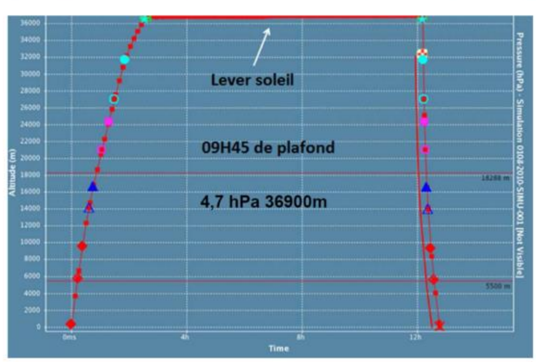


[1] M. J. Wilby and Al. "The coronagraphic Modal Wavefront Sensor: a hybrid focal-plane sensor for the high-contrast imaging of circumstellar environments", A&A 597, A112 (2017)

HiCIBaS

Preliminary Mission Analysis

CARMEN
- **Constant ceiling**
- **402Z Balloon**
- **13 hours**



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HiCIBaS

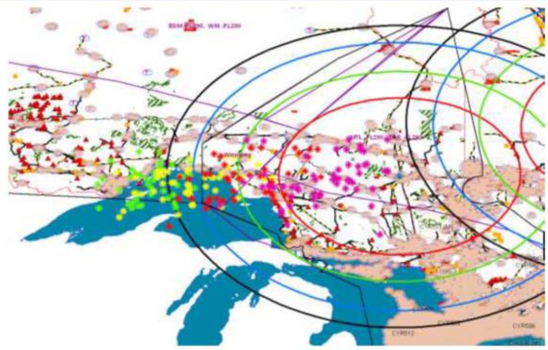
Preliminary Mission Analysis

CARMEN

- Separation points

- green: from 01 to 07
- yellow: from 08 to 15
- red: from 16 to 21
- purple: from 22 to 31

Keep for the end



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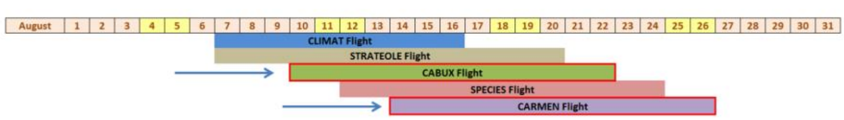
HiCIBaS

Flight Windows



CABUX: **CA**laset - strato**BU**s - **X**enon

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HiCIBaS: Pointing System

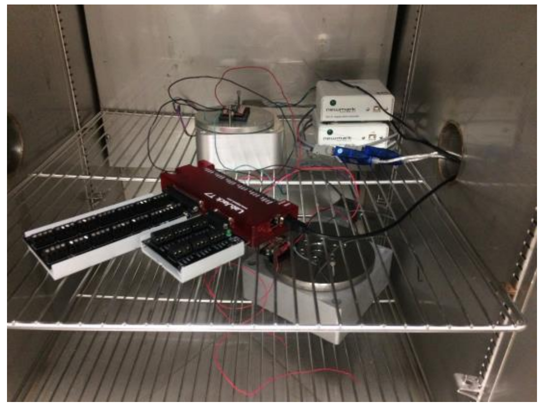
Tests in cold environnement

Tested components:

- Motors (RM3, RM5, RM8)
- Motor Controlers
- Labjack T7
- Gyrometers

- Target Temperature:
  - -55°C

- Humidity:
  - 0% (target)
  - Not sure if the chamber cleared all humidity.

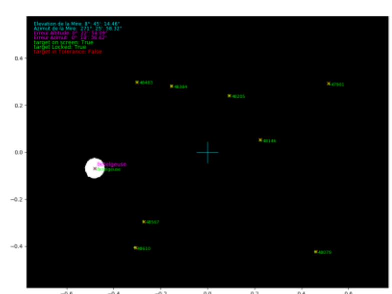


HiCIBaS: Pointing System

On sky localisation

- Test of the star identification algorithm on real sky image.

- Partial succes:
  - We need a wider FOV.



HiCIBaS: LOWFS

On-sky test of LOWFS

Université Laval's AO test-bench

- 97 actuator deformable mirror
- Optocraft Shack-Hartmann Sensor
- Andor iXION emccd science camera
- HNü128 PWFS cam

Observatoire du Mont Mégantic's 1.8m telescope

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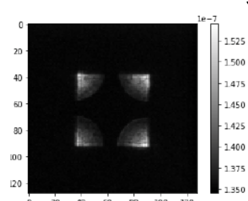
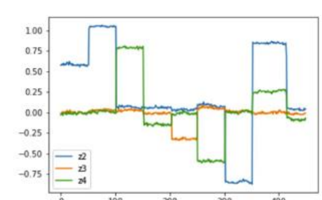
HiCIBaS: LOWFS

On-sky test of LOWFS

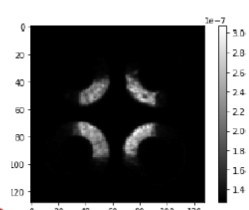
Sucessful reconstruction

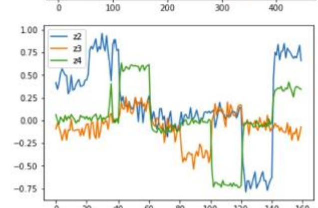
Laser source





On-sky





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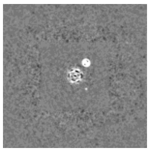
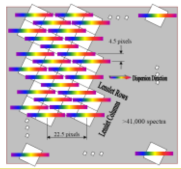
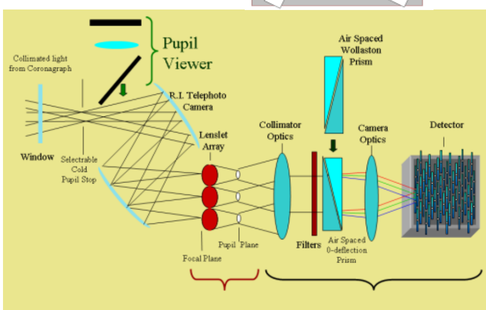
GPI: GEMINI PLANET IMAGER

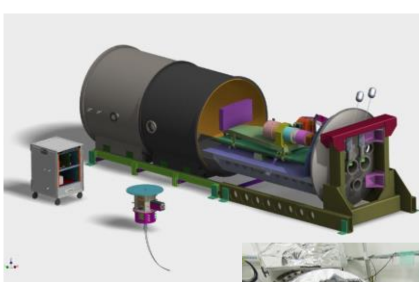


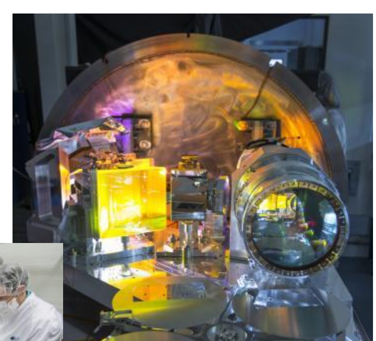




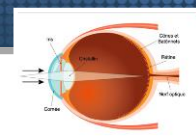
coll. with UCLA

SPIROU -- NIRPS



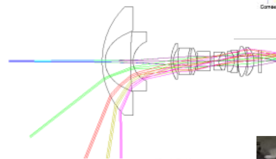


LRIO

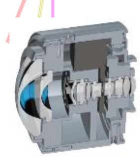


Innovative Concept

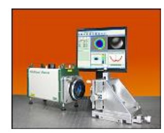
Design and Simulation



Modern Assembly



State of the Art Fabrication & Testing



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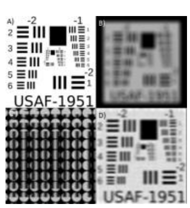
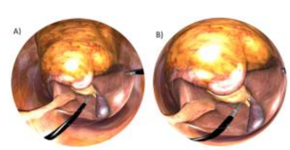
Miniaturization of wide angle cameras

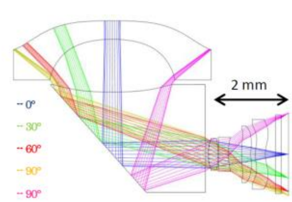
Xavier Dallaire, PhD student

Aberration correction using microlens array



Folded foveated design





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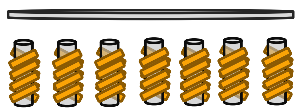
Deformable mirrors from polymer/magnetic nanoparticle composites

Renaud Lussier, PhD student

Co-supervisor: Anna Ritcey

- Objective: Design and assembly of new magnetically deformable mirrors from an elastomer material and magnetic nanoparticles

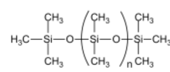
Magnetic membrane



Features:
- Uniform material
- Actuation system independent from the deformable surface
- Cheap components

Nanoparticles

Aluminium deposition



Elastomer

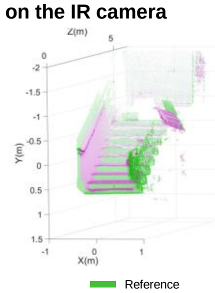
Dedormable mirror

Wide angle 3D vision system based on Kinect V2

Co-supervisor: Marc-Antoine Legault

- Phase 1
  - Analyse the Kinect
  - Find the issues
- Phase 2
  - Optical design
- Phase 3
  - System implementation
  - Test in operating conditions

Adding lens on the IR camera



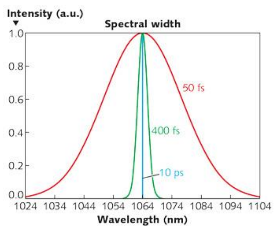
Calibration → Correction

Institut du véhicule innovant

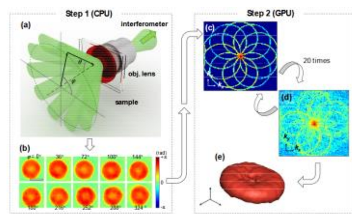
Diffraction tomography based on holography and ultrashort laser pulses

Co-supervisor: Prof. Pierre Marquet

- Wide spectral bandwidth of ultrashort pulses can be used as new degree of freedom
- Applied to diffraction tomography for 3D spectral measurements



Source : www.laserfocusworld.com



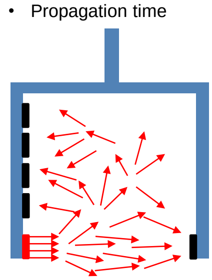
Source : Kyoohyun Kim et. Al, "Real-time visualization of 3-D dynamic microscopic objects using optical diffraction tomography," Opt. Express **21**, 32269-32278 (2013)

Through the automatic measurement of snow properties

Félix Lévesque-Desrosiers, master's student

Co-supervisor: Prof. Florent Dominé

Measurement of:
- Transmittance
- Back-scattering
- Propagation time

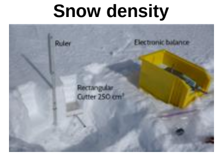


$I_{in} = I_0 \sin(\omega t)$

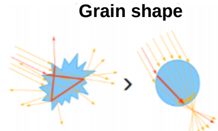
$I_{out} = I_0 T \sin(\omega t + \phi)$

Inversion

Snow density



Grain shape



Grain size

TAKUVIK

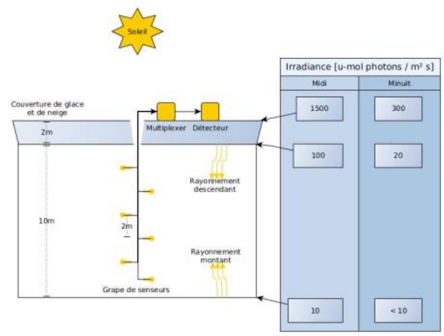
Sentinel North

Detection of underwater PAR radiation using optical fibers

Gabriel P. Lachance, master's student

Supervisor: Sophie Larochelle, Co-supervisor: Warwick F. Vincent

- Detection system for PAR radiation.(«Photosynthetically Active Radiation»).
- Underwater applications in arctic lakes.
- Able to detect the dim radiation under a thick layer of ice and snow.
- Optical sensors to increase the radiation gathering capacities of the system.
- Transfer of the signal to the surface using optical fibers.
- Array of sensors able to gather radiation simultaneously at different depth.



Sentinel North

Neural network-based lens design optimization algorithm

Geoffroi Côté, master's student

Co-supervisor: Jean-François Lalonde

- Lens design optimization is known for its difficulty
  - The many variables involved share a complex relationship
  - Physical constraints tend to complicate the design process
- The traditional computer-assisted lens design process is flawed
  - It requires the optical engineer to provide a viable initial design
  - Computed aided design can further improve the initial design by local damped-least-squares optimization which can only modify parameters locally
  - Some global design methods have been proposed, but they are largely based on heuristics which do not fully use the structure of the data
- This project aims to use machine learning approaches to improve the design process by learning from previous designs
  - Specifically, neural networks can be used in the context of meta-learning, or learning to learn
  - A neural network trained on previous data can guide the optimizer during its search for better local optima in fewer iterations

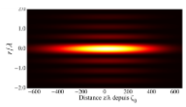
Laboratoire de Vision et Systèmes Numériques

Towards engineering systems under extreme focusing conditions

Jeck Borne, master's student

Co-supervisor: Michel Piché

Theory



The group proposed an extension to the Richards-Wolf theory describing non-paraxial light focusing. This extension provides the basis to work on imperfect spherical wavefront focusing systems such as conic mirrors. Using this formalism, needles of light and beam analytical solutions are straightforward to obtain.

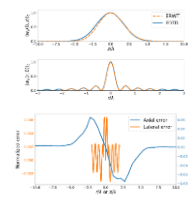
$$\begin{Bmatrix} E_r \\ E_z \end{Bmatrix} \propto \int_{\alpha_{min}}^{\alpha_{max}} q(\alpha) l_0(\alpha) \sin\alpha \begin{Bmatrix} \sin\alpha J_0(kr\sin\alpha) \\ i\cos\alpha J_1(kr\sin\alpha) \end{Bmatrix} \exp\left(i\phi(\alpha,z)\right) d\alpha$$

$$\phi_e = -\gamma \left[Z\cos\alpha + \rho\cos\theta + \rho\frac{\sin\theta}{\sin\alpha} - \zeta\cos\alpha \right]$$

$$q_e(\alpha) = \sqrt{\frac{\rho\sin\theta\left(\frac{d\rho}{d\theta}\sin\theta + \rho\cos\theta\right)\left(\frac{d\alpha}{d\theta}\right)^{-1}}{\kappa'\sin\alpha}}$$

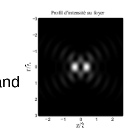
Numerical simulation

To compare the extension with solutions of Maxwell's equations, the group opted to use FDTD algorithm. Results are consistent and robust. Further studies will show the effects of aberrations and various surface defects on the fields. Note, these profiles couldn't be computed using the classical Richards-Wolf theory.



Objectives

- Beam shaping optimization;
- Electron acceleration;
- Enhanced microscopy maximum resolution and use needles of light.



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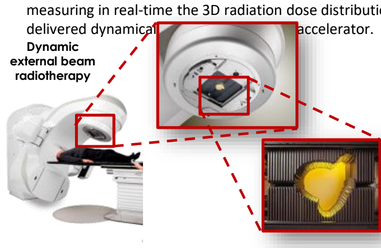
Development of a 3D scintillation dosimetry system for clinical use in external beam radiotherapy

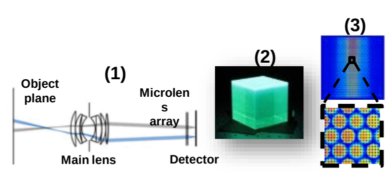
Madison Rilling, PhD student

Co-supervisor: Louis Archambault

Context

In radiotherapy cancer treatments, dosimetry systems play an essential role of quality assurance. In a clinical context where a great number of patients need to be treated with optimal precision and efficiency, there is a need for a user-friendly tool capable of measuring in real-time the 3D radiation dose distribution delivered dynamically by a linear accelerator.





Research project

We take advantage of optical engineering techniques to solve a complex and growing problem in medical physics. The envisioned system uses a plenoptic camera **(1)** to image the light field emitted from an irradiated plastic scintillator volume **(2)**. An iterative tomographic reconstruction algorithm serves to recover the 3D distribution from the acquired plenoptic images **(3)**. Ultimately, the pr[oblem boils] down to finding a continuously-changing 3D ligh[t distribution] emitted within a translucent volume.

Using a ray tracing software, we aim to model, design and optimize the system components to design a clinical prototype.

CENTRE DE RECHERCHE SUR LE CANCER

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