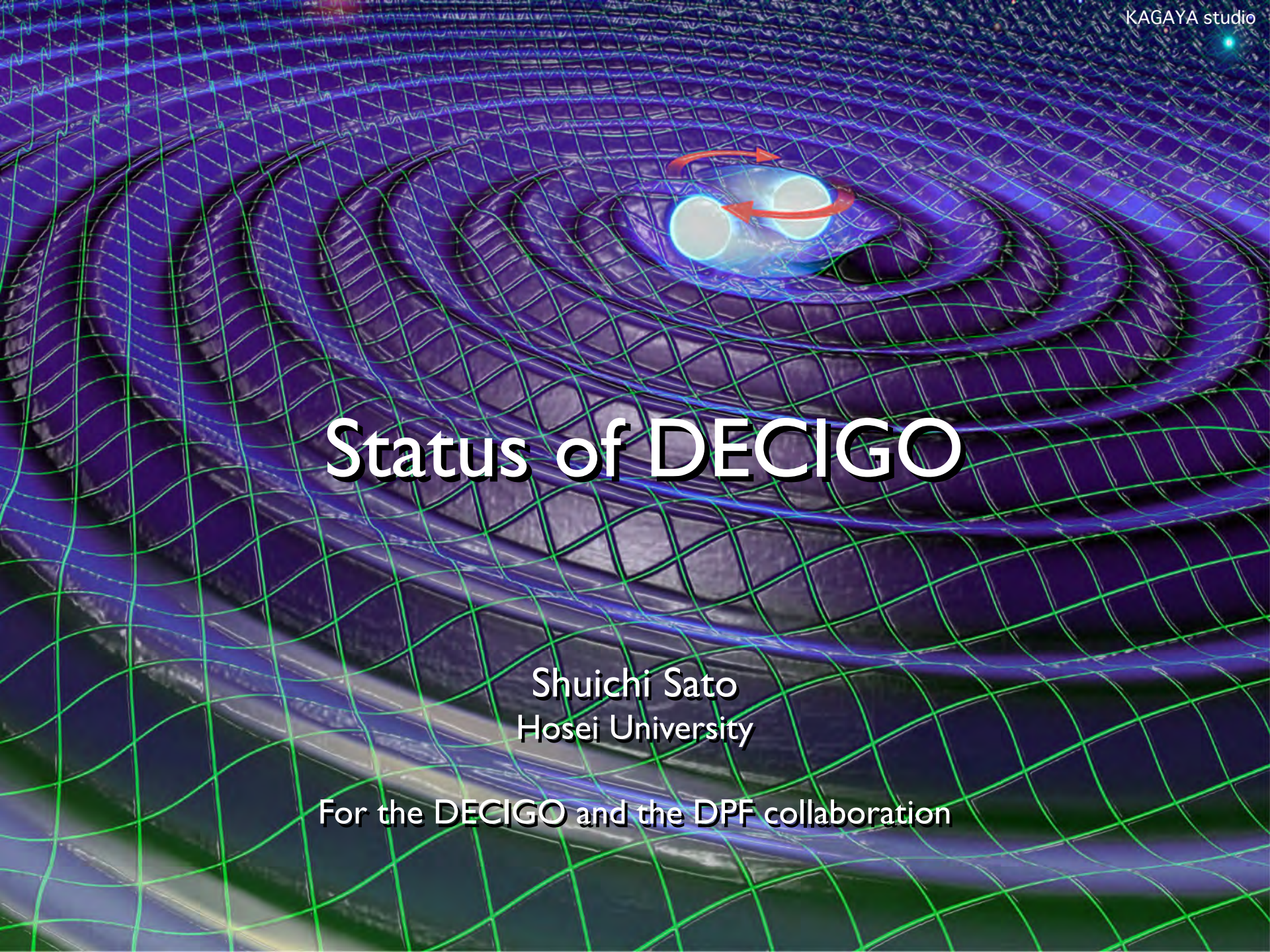


Status of DECIGO

Shuichi Sato
Hosei University

For the DECIGO and the DPF collaboration

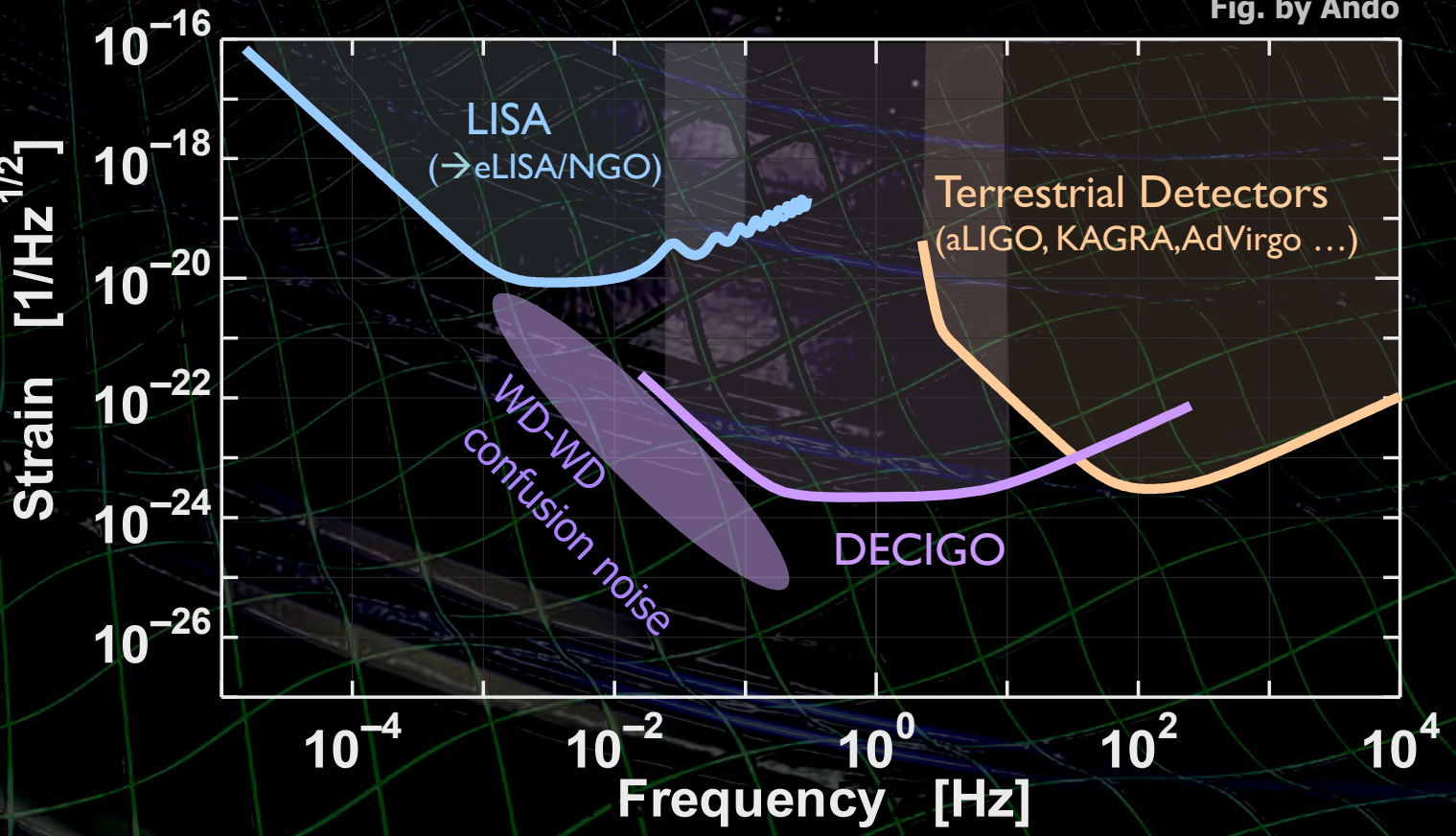
Outline

- DECIGO
- DECIGO pathfinder
- Mission status

Idea of DECIGO

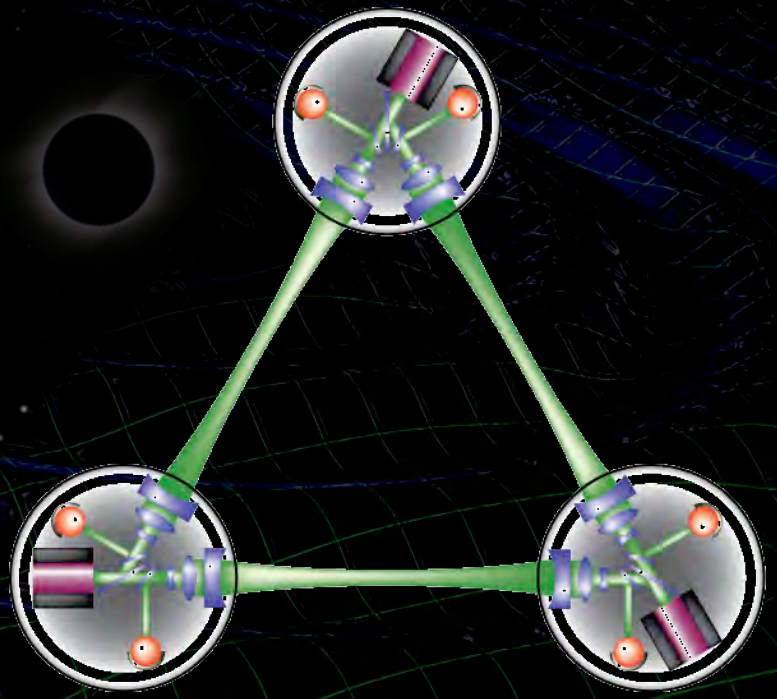
- DECi-hertz Interferometer Gravitational wave Observatory
  - Seto, Kawamura and Nakamura, *PRL87, 221103(2001)*
  - Bridges the gap between LISA and terrestrial detector
  - Low confusion noise → Potentially high sensitive instruments

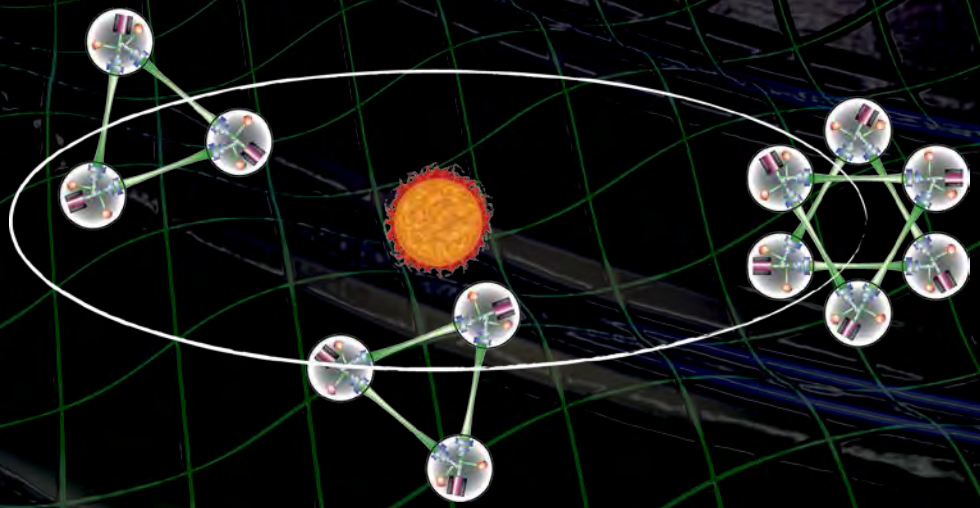
Fig. by Ando



Pre-conceptual design

- Interferometer topology
  - Differential FP interferometer
  - Three interferometers for redundancy
  - Drag-free controlled S/Cs
- Constellation
  - 4 interferometer units
  - 2 overlapped units → Cross correlation
  - 2 separated units → Angular resolution





Arm length:	1000 km
Mirror diameter:	1 m
Mirror mass:	100 kg
Laser wavelength :	532 nm
Laser power:	10 W
Finesse:	10

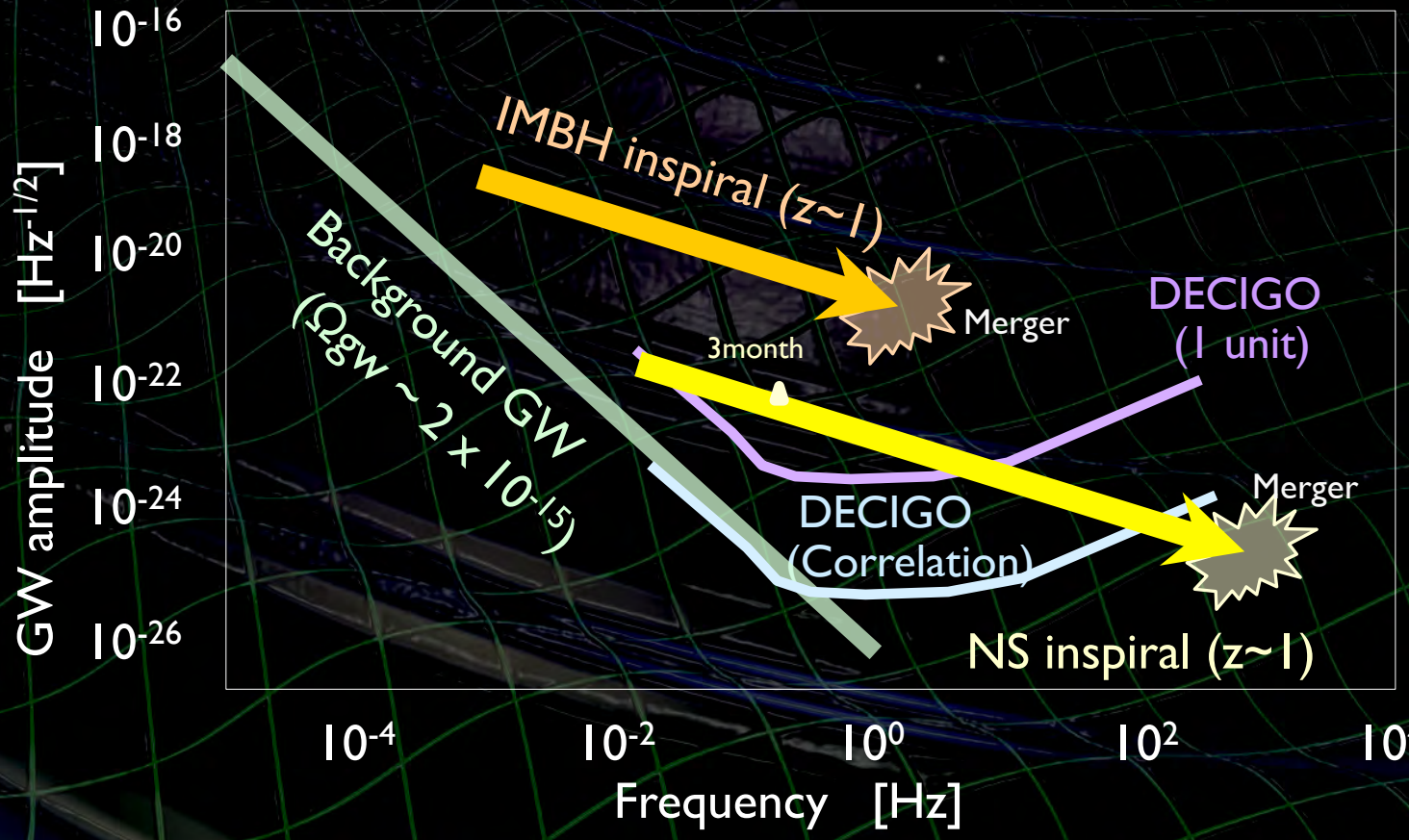
Science of DECIGO

- IMBH binary inspiral
- NS binary inspiral
- Stochastic background

⇒

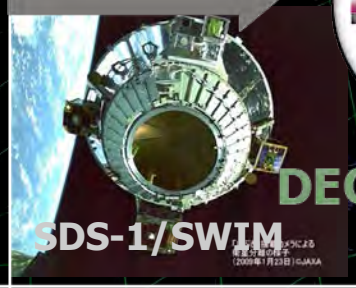
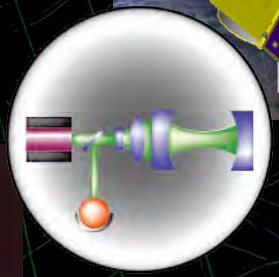
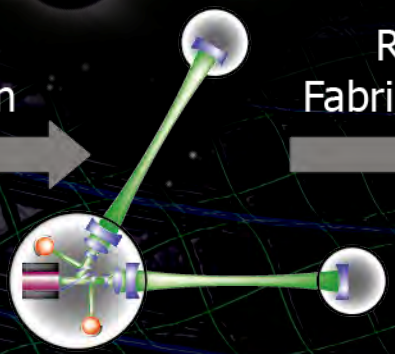
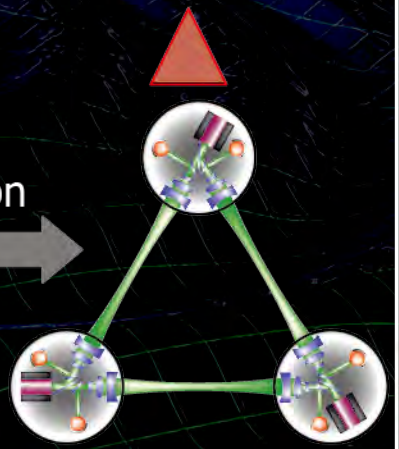
- Galaxy formation (Massive BH)
- Cosmology (Inflation, Dark energy)
- Fundamental physics

Fig. by Ando



Roadmap

Fig. by Kawamura, rev.

	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
Mission	R&D Fabrication								R&D Fabrication						R&D Fabrication					
	 SDS-1/SWIM								 DECIGO Pathfinder (DPF)						 Pre-DECIGO					 DECIGO
Objectives	Test of key tech. in orbit GW detection Earth gravity observation								Detection of GW w/ min. spec. FP cavities between S/Cs						GW astronomy					
Scope	Single small S/C Short FP interferometer								3 S/Cs, single IFO Single unit						3 S/Cs, 3 IFOs 3 or 4 units					

Key technologies for DECIGO

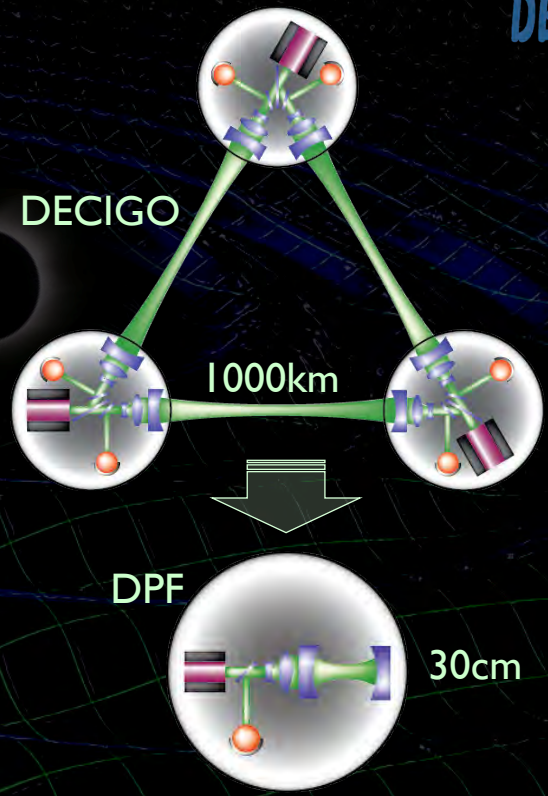
- Precision measurement in orbit
  - laser interferometry : Fabry-Perot cavity
  - All dof drag-free control
  - Demonstration by DPF
- Precision formation flying technique
  - Long-baseline formation flight : km scale
  - mm scale precision
  - Demonstration by Pre-DECIGO

DECIGO pathfinder (DPF)

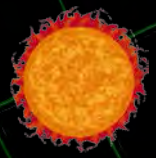
- First precursor satellite for DECIGO

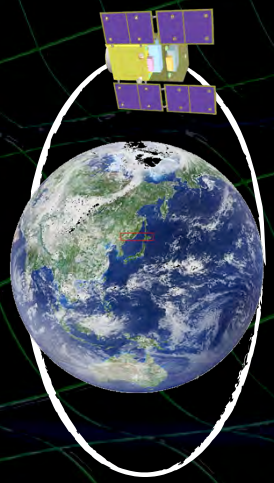
DECIGO: 1000km baseline
Formation flying S/Cs

DPF: 30cm baseline
Single satellite



- Mission scale : ~450kg
- Orbit : Low earth orbit, 500km
  (sun synchronous polar orbit)
- Launch vehicle: Next-generation
  Solid rocket booster (M-V FO)
- Apply for JAXA's
  "Small science satellite series" program





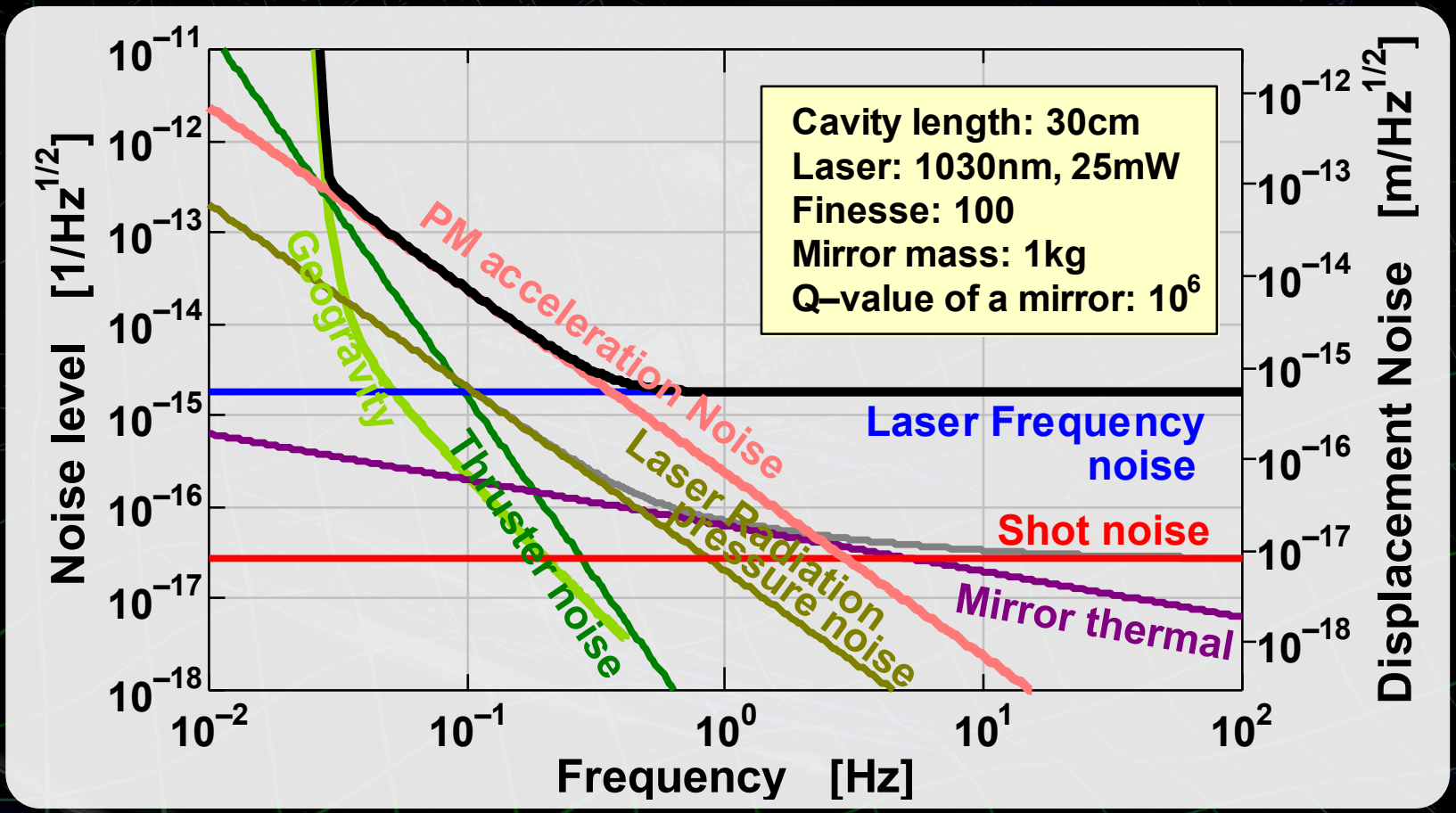
Sensitivity of DECIGO pathfinder

Laser source : 1030nm, 25mW
IFO length : 30cm
Finesse : 100, Mirror mass : 1kg
Q-factor : 10^5, Substrate: TBD
Temperature : 293K

Satellite mass : 450kg
Altitude: 500km
Thruster noise: 0.1μN/Hz$^{1/2}$

(Preliminary parameters)

Fig. by Ando



DPF satellite overview

DPF Payload

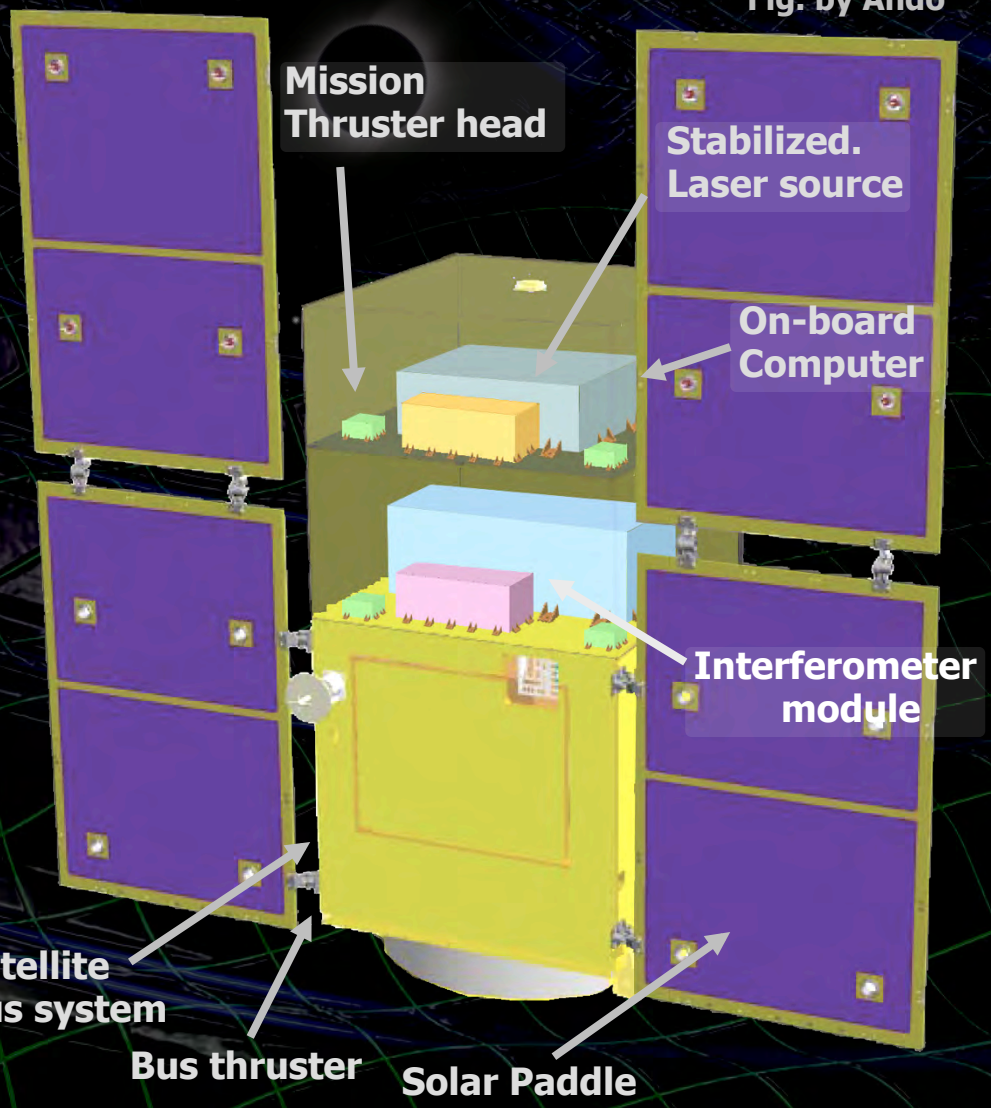
Size : 950mm cube
Weight : 200kg
Power : 130W
Data Rate: 800kbps
Mission thruster x10

Power Supply
SpW Comm.

Satellite Bus

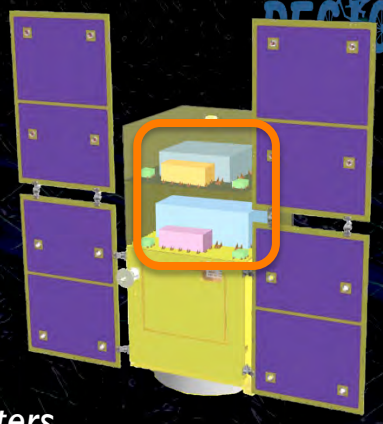
('Standard bus' system)
Size : 950x950x1100mm
Weight : 250kg
SAP : 960W
Battery: 50AH
Downlink : 2Mpbs
DR: 1GByte
3N Thrusters x 4

Fig. by Ando



DPF mission system (schematic)

Mission weight : ~150kg (200kg for bus)
Mission space : ~95 x 95 x 90 cm



Drag-free control
Local sensor signal
→ Feedback to thrusters

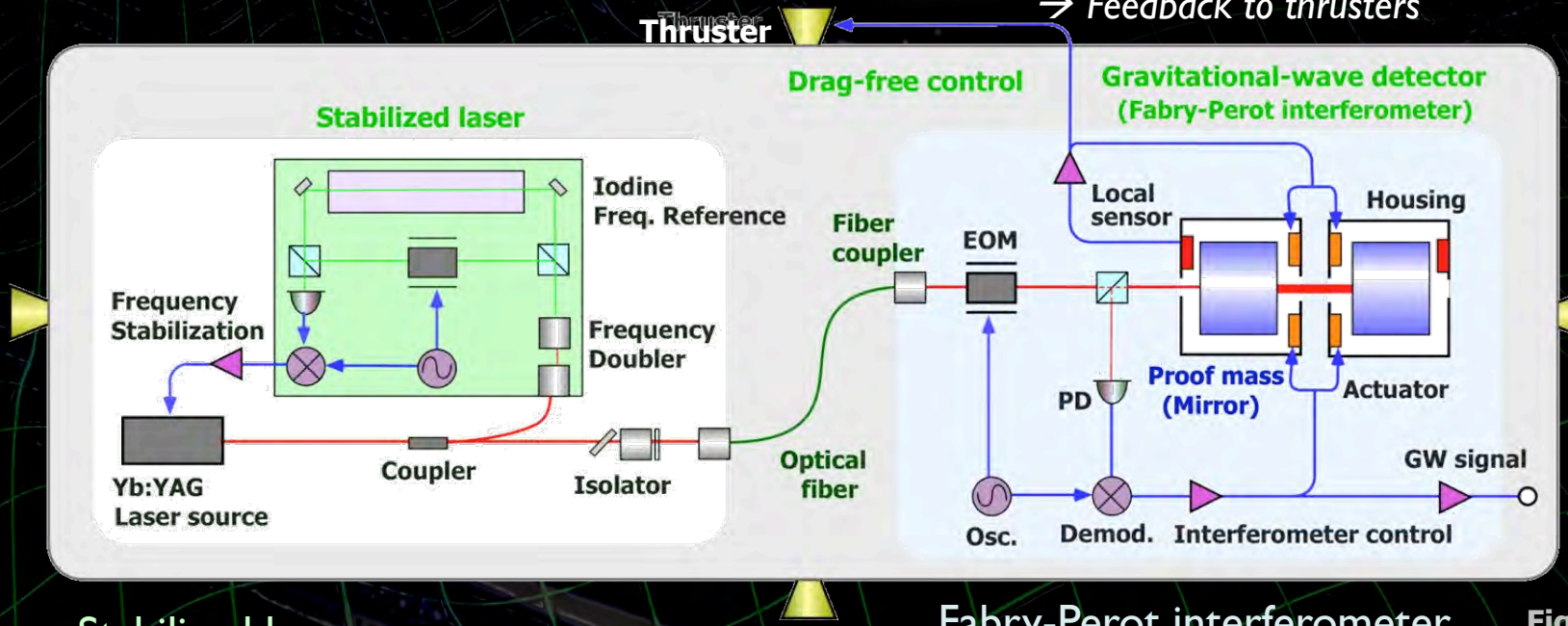


Fig. by Ando

Stabilized laser

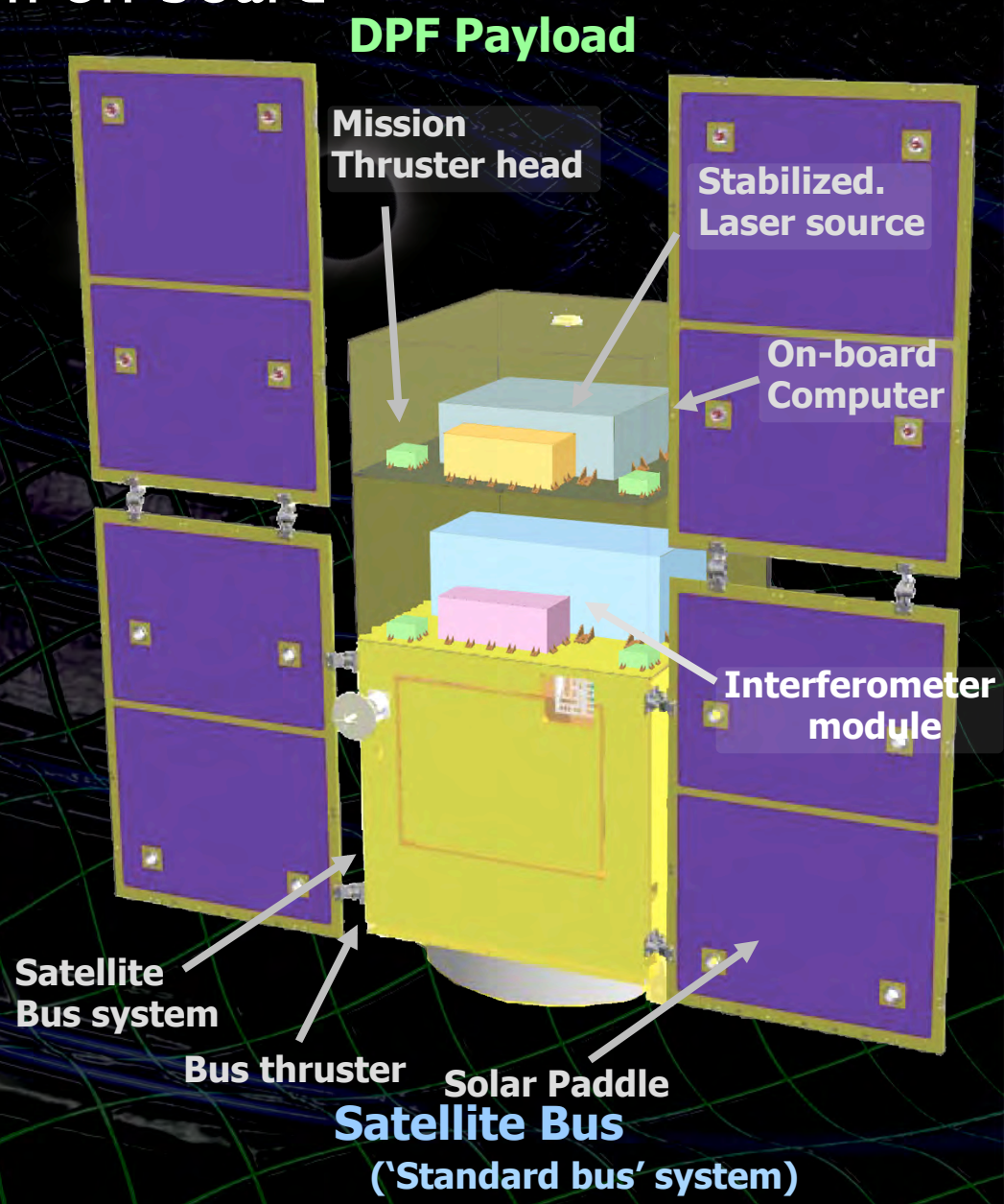
Yb: fiberDFB laser (1030nm)
Power : 25mW
Freq. stab. by Iodine absorption line

Fabry-Perot interferometer

Finesse : 100
Length : 30cm
Test mass : ~1kg
Signal extraction by PDH

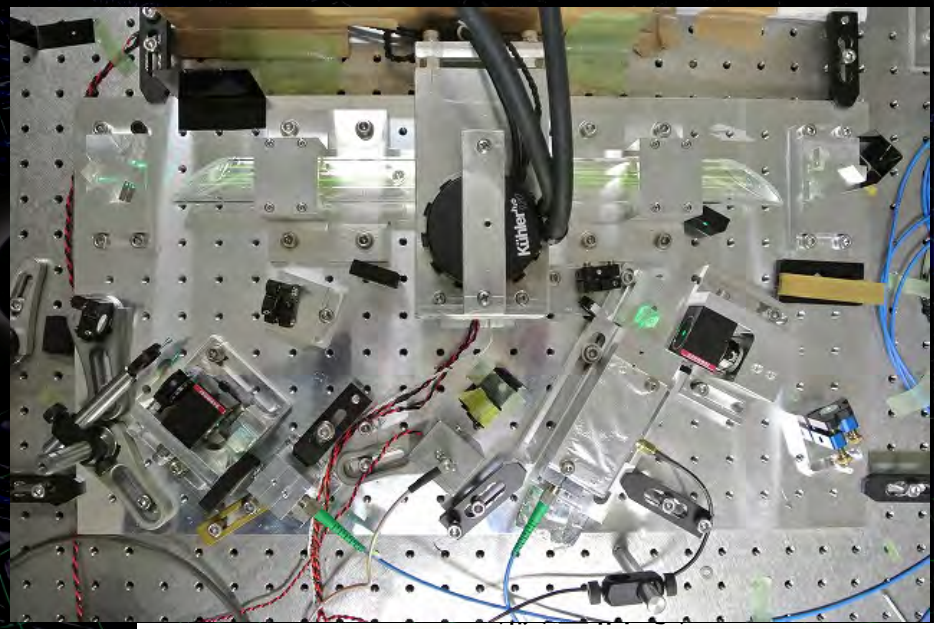
Mission module/system on-board

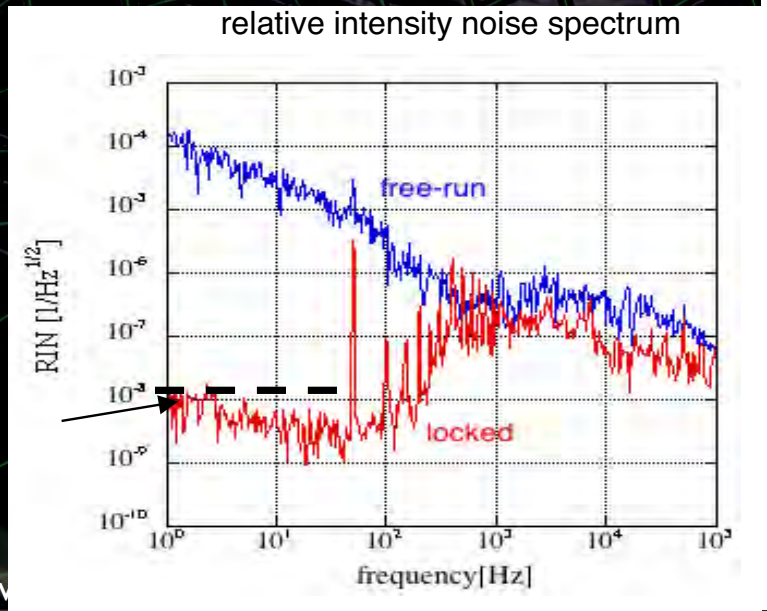
- Interferometer module
  - Test mass module
    Test mass, caging frame, laser sensor, Electro static sensor/actuator, Test mass lock mechanism, Charge management system
  - Input/output optics
    Monolithic optical bench, PDH control, WFSs, MMT
  - Structure/shielding system
    Support frame, thermal shielding, Vacuum enclosure
- Stabilized laser module
- Drag-free control system
- Signal processing/control system

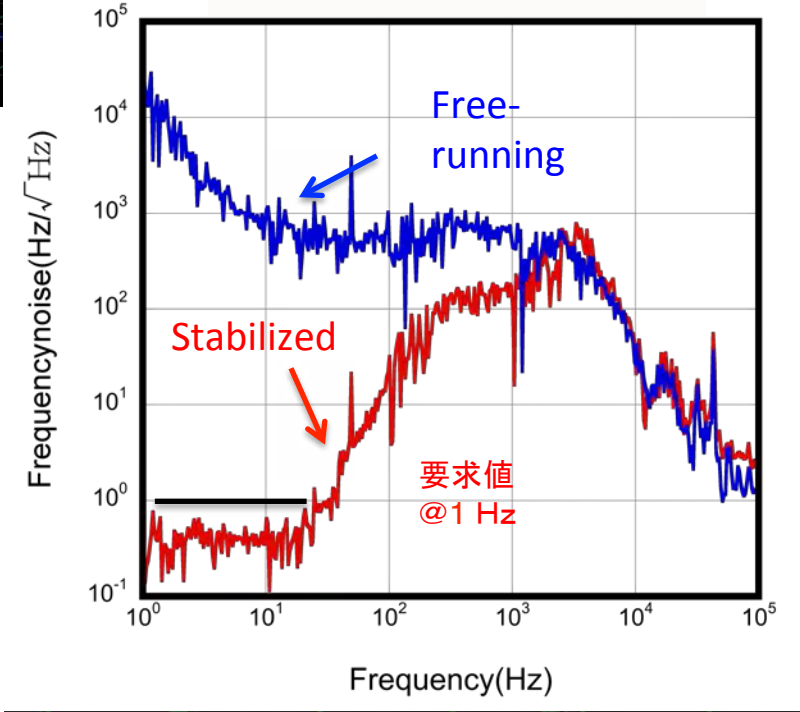


Stabilized laser module

- Laser source
  - Yb: Fiber DFB laser 1030nm (20mW)
  - YDFA amplifier (250mW)
    Compact and light, Vibration resistant
- Frequency stabilization
  - Iodine cell
    Vibration resistant, Long-term stability
  - Absorption line: 515nm
  - Stability: 0.4 Hz/rtHz @ <10Hz
- BBM Size: W550 x D300 x H82 mm

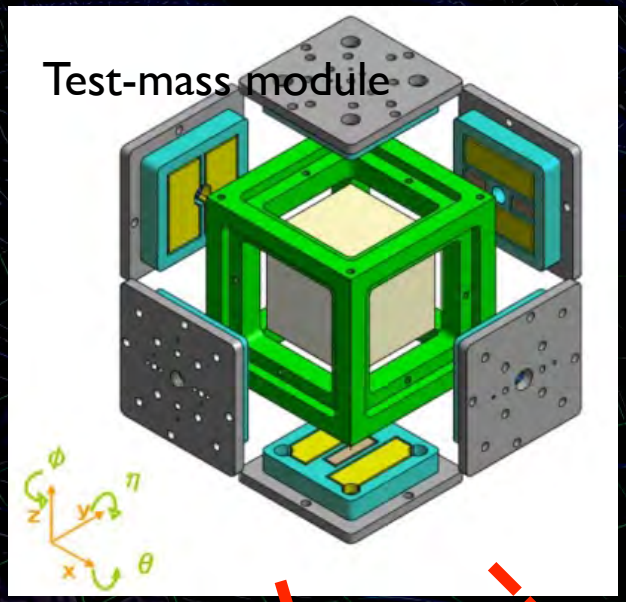






Interferometer module

- 2 Test mass modules
  Test mass, caging frame,
  Electro static sensor/actuator,
  Test mass lock mechanism,
  Charge management system
- Input/output optics
  Monolithic optical bench, PDH control,
  WFSs, MMT
- Structure/shielding system
  Support frame, thermal shielding,
  Vacuum enclosure (10-6Pa)



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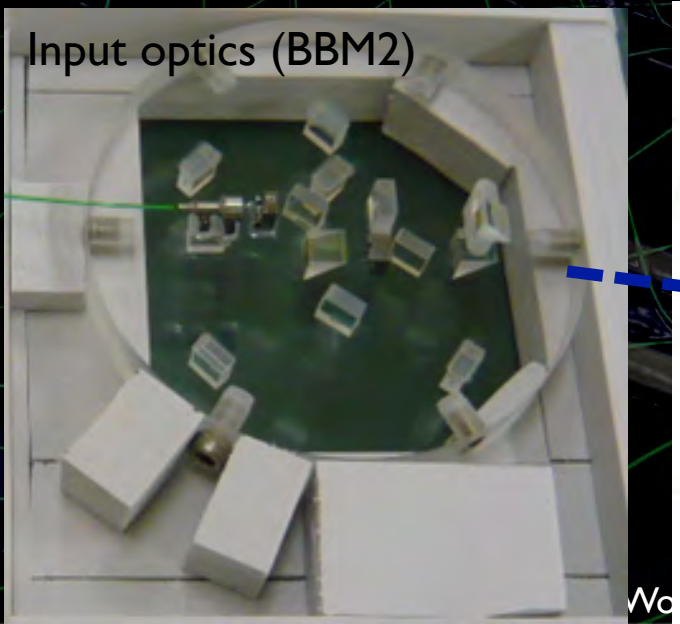
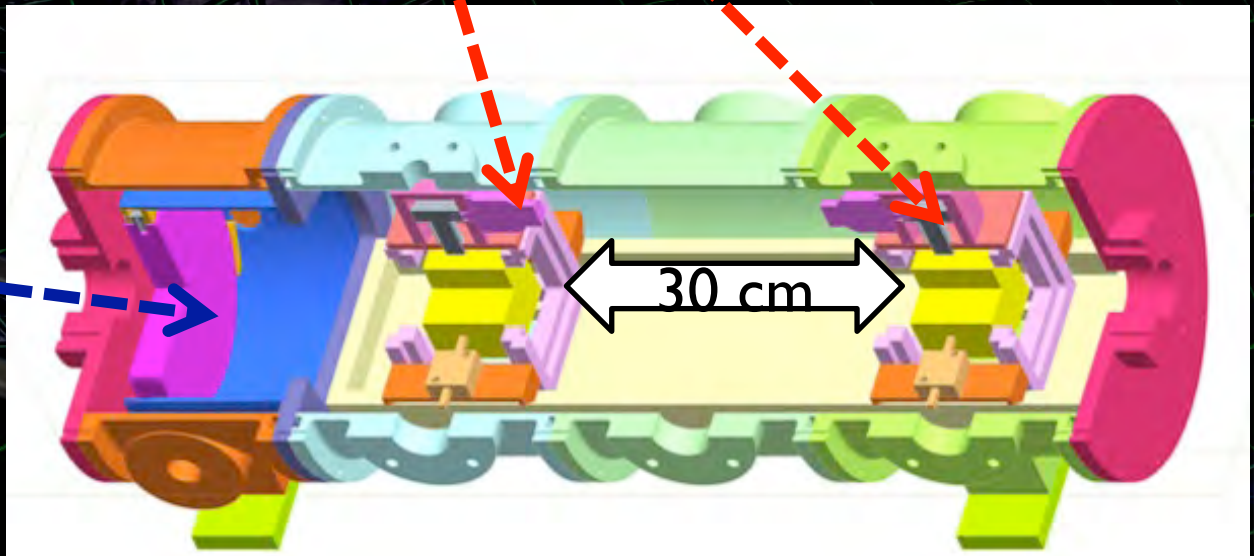
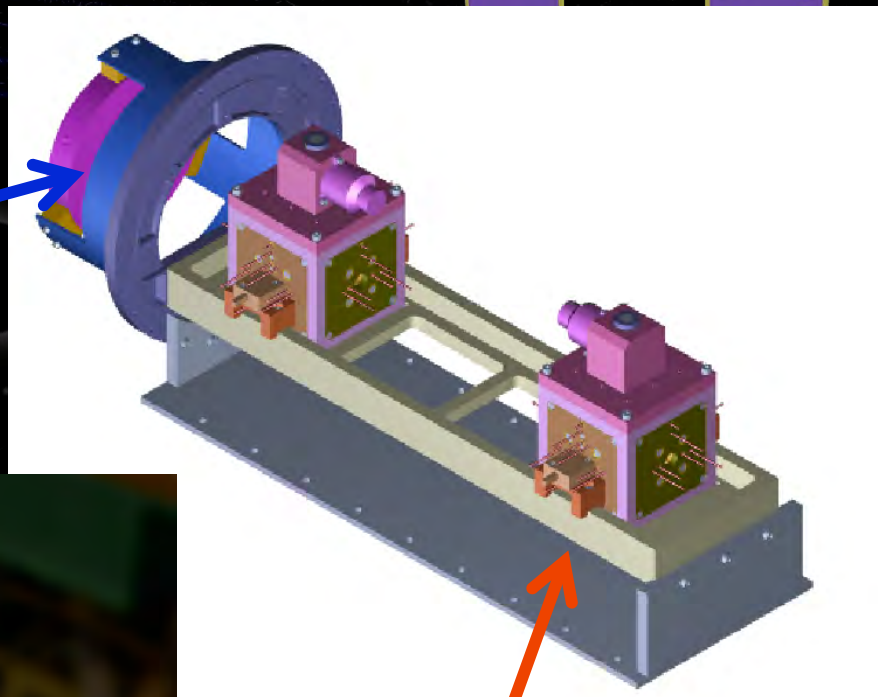
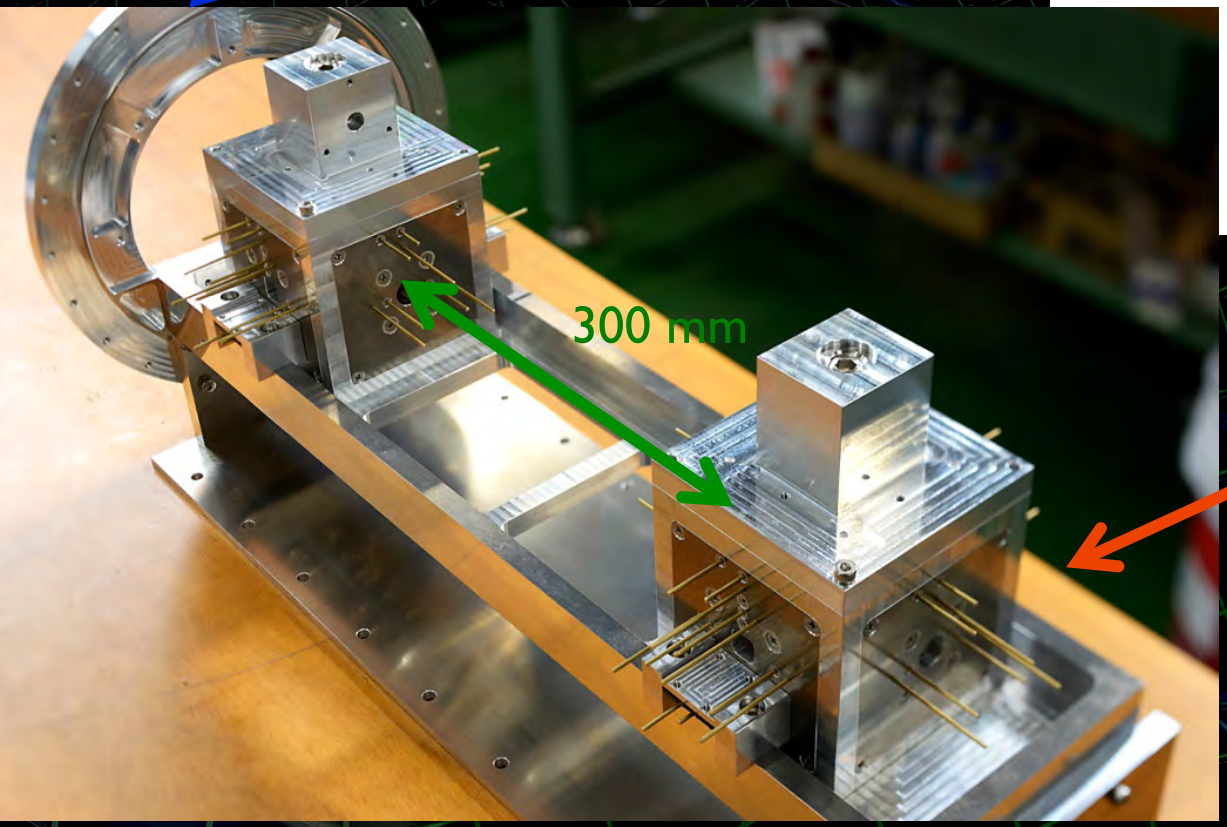




Interferometer module

Monolithic input optics

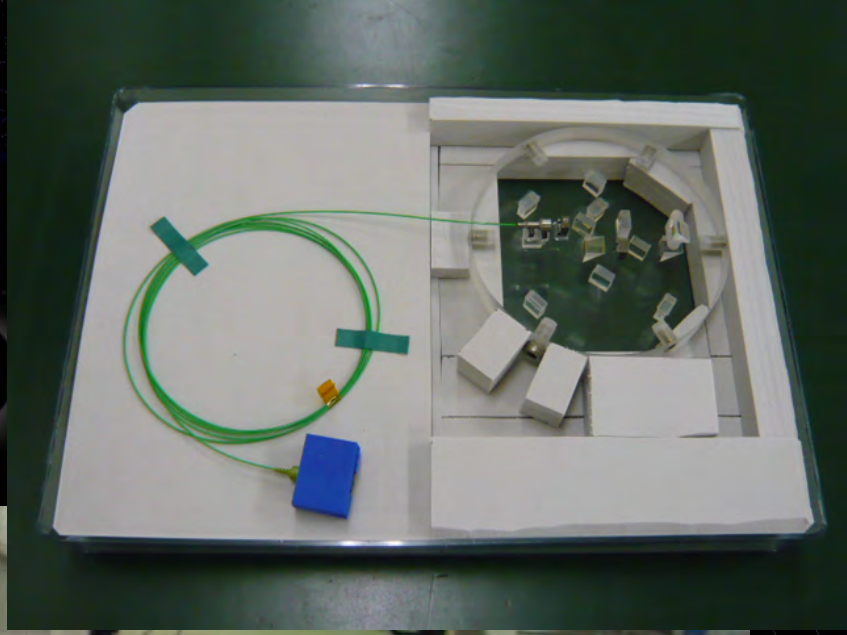




Test mass module

Input/output optical system

- Monolithic optical bench
- Silicate bonding
- Compacted for IFO BBM, ø120mm
- Optics bonded on both sides



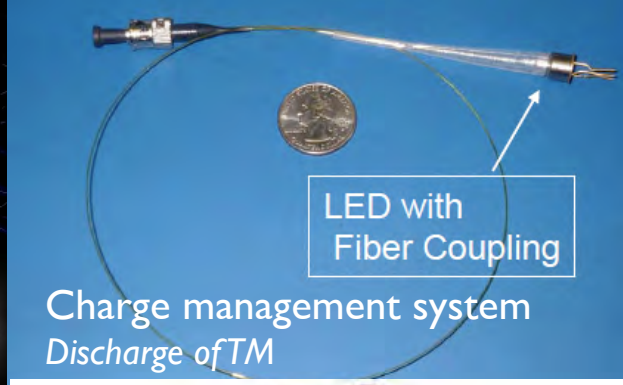
Input optics (BBM2)

Cavity (300mm)

2014

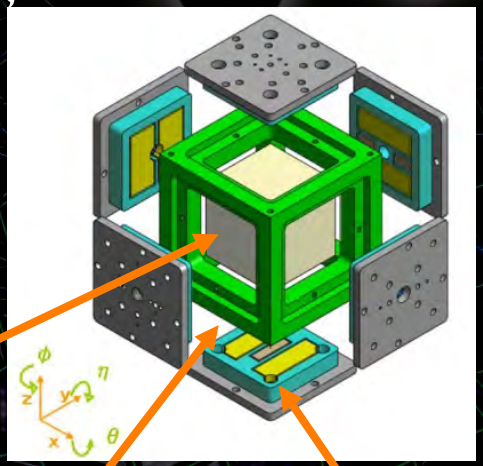
Test-mass module

- Test mass
- Caging frame
- Electro static sensor/actuator,
- Test mass lock mechanism,
- Charge management system

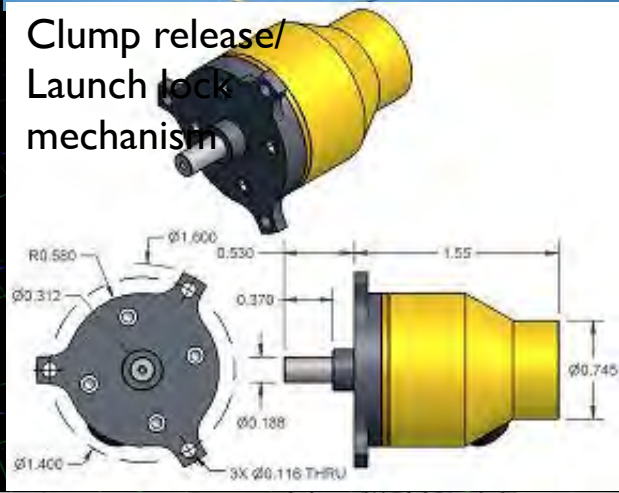


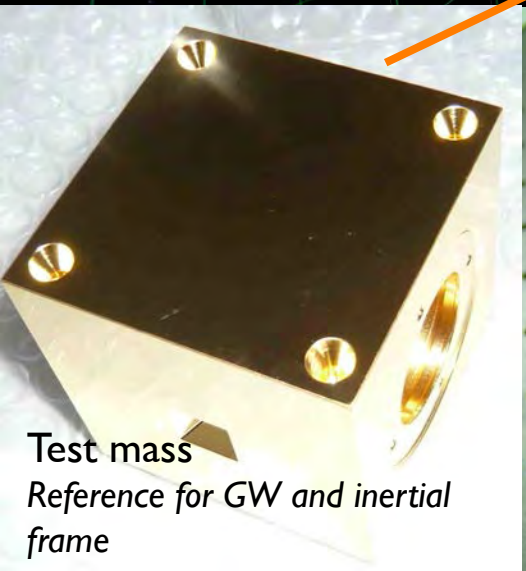
Charge management system
Discharge of TM

Test mass module

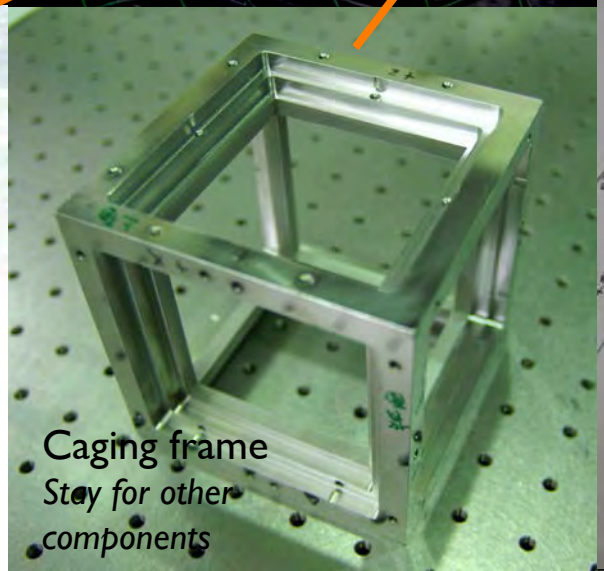


Clump release/
Launch lock
mechanism

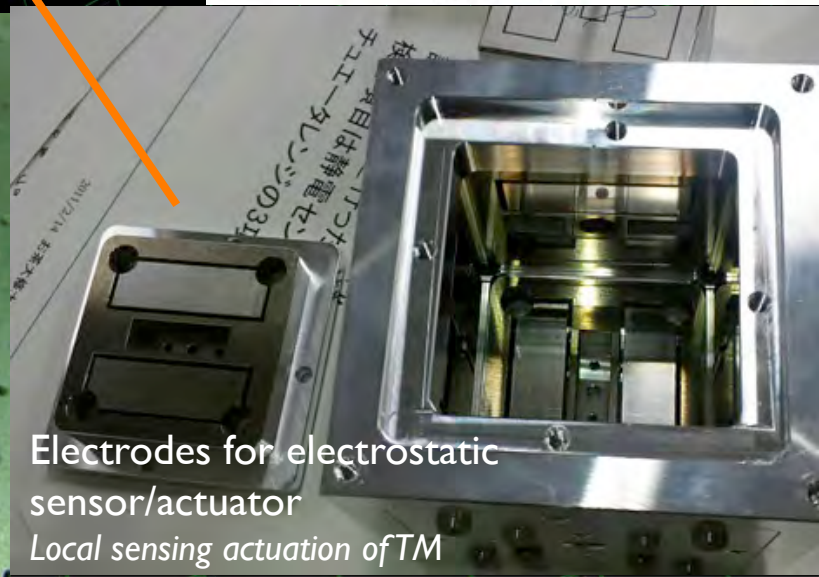




Test mass
Reference for GW and inertial frame



Caging frame
Stay for other components

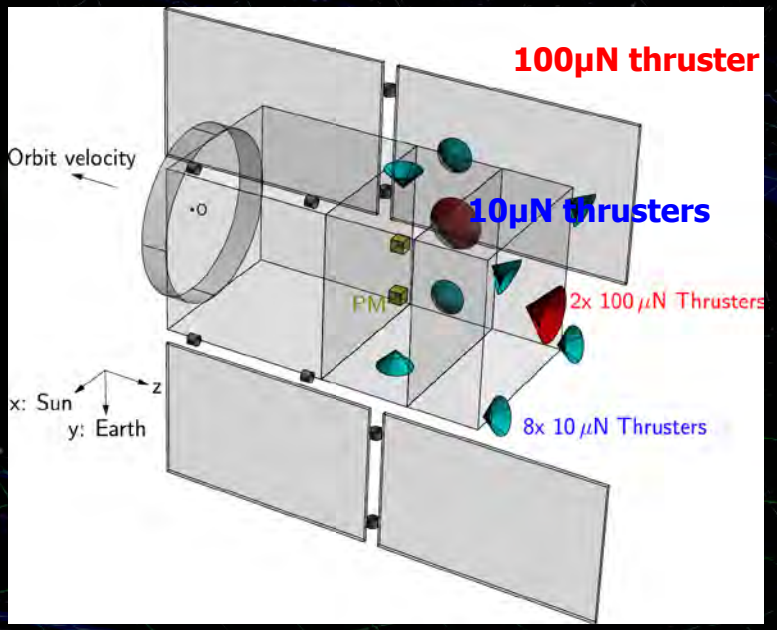


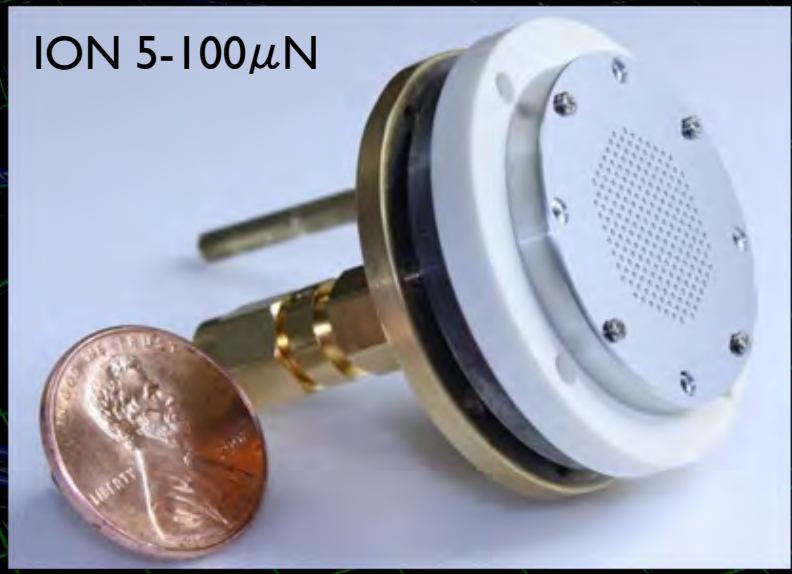
Electrodes for electrostatic sensor/actuator
Local sensing actuation of TM

Drag free control

- Concept
  - Control S/C with reference to TMs
  - Diff. modes to TMs
  - Comm. modes to S/C
  - Using hierarchical control
- Disturbance source @LEO500km
  - Solar radiation pressure: 20μN@DC
  - Air drag: typ.100μN@DC
    Annual/season dependent
- Micro Thruster
  - 10μN thruster x8 for drag free control
  - 100μN thruster x2 for DC drag cancellation
  - FEEP, Cold gas jet, Ion thruster
- Attitude control
  - Should work w/o thrusters
  - Passive: owing to S/C shape
  - Active: MTQ control

Fig. by Moriwaki

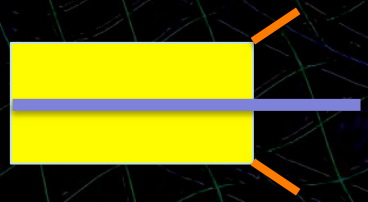




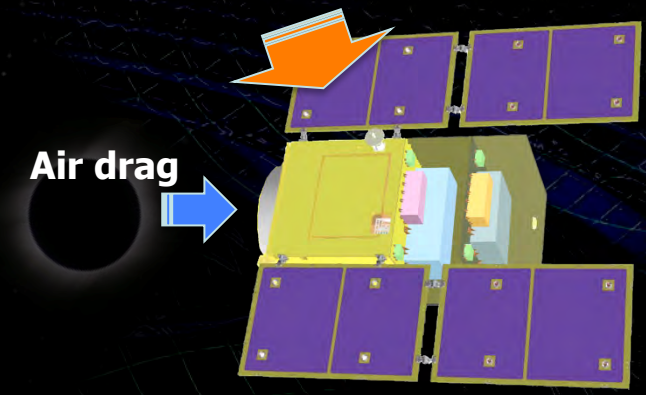
Attitude/Drag free control

- Passive control
  - "weathercock" stability (for air drag)

SAP as "wing"
Fin as "tail"



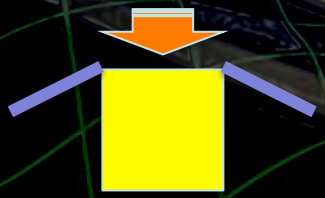
Solar radiation drag



- Cant for SAPs (for solar radiation drag)

Cant angle
SAP position to the S/C frame

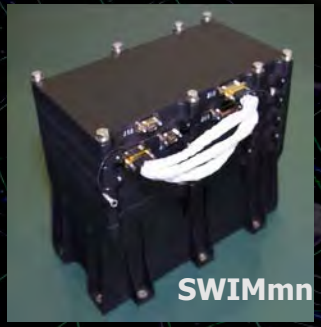
Solar radiation drag



©NEC

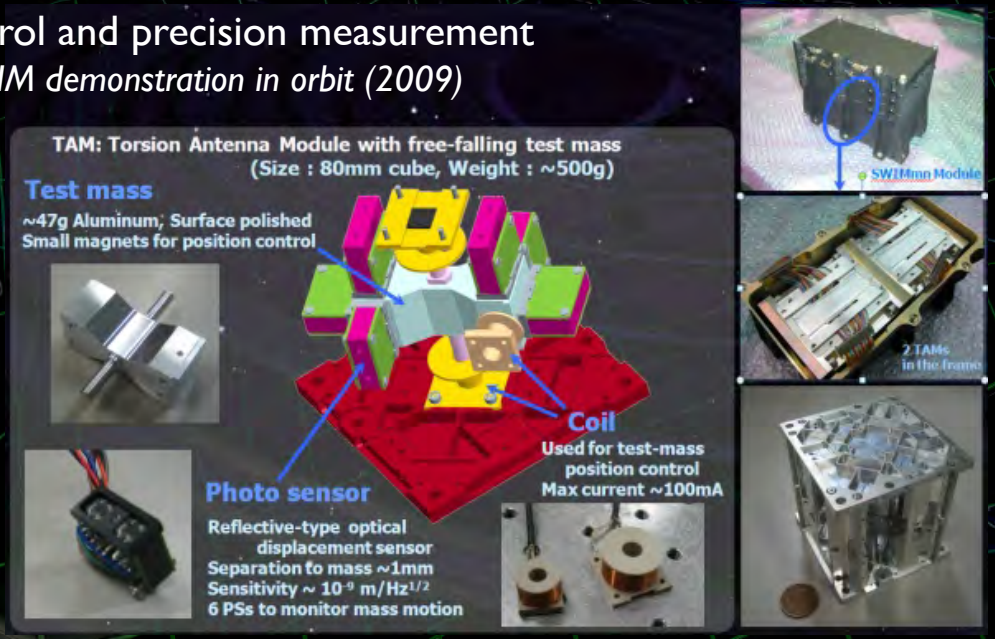
Signal process/control syste

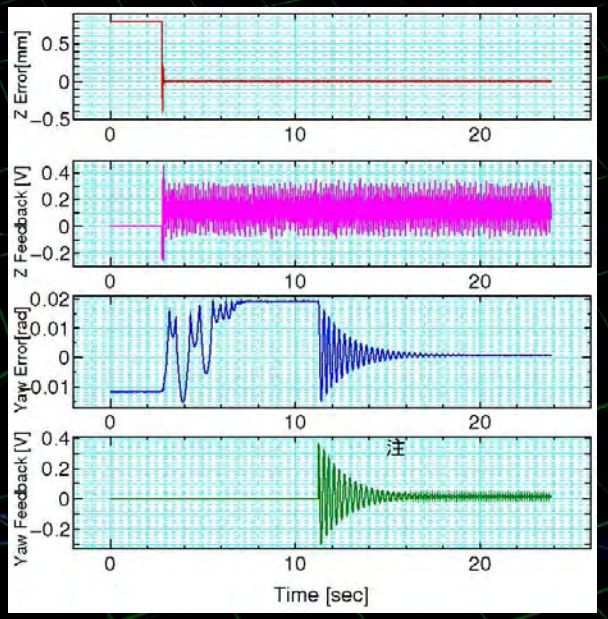
- Space Wire based system
  - Demonstration in orbit
    - *SWIM on SDS-1*
    - *Space Cube 2 (SpC2))+Space Wire (SpW) system*



JAXA, U-Tokyo, Kyoto-U

  - Control and precision measurement
    - *SWIM demonstration in orbit (2009)*





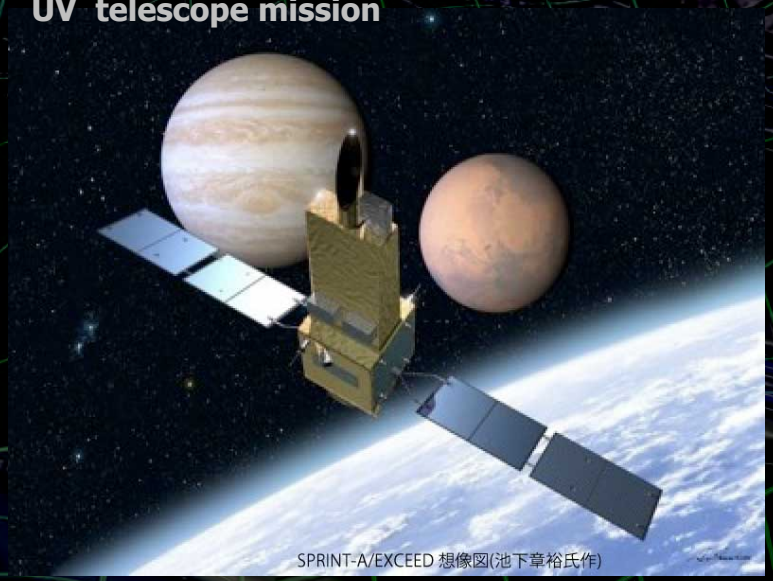
Mission status of DECIGO pathfinder

- JAXA's "Small science satellite series" program

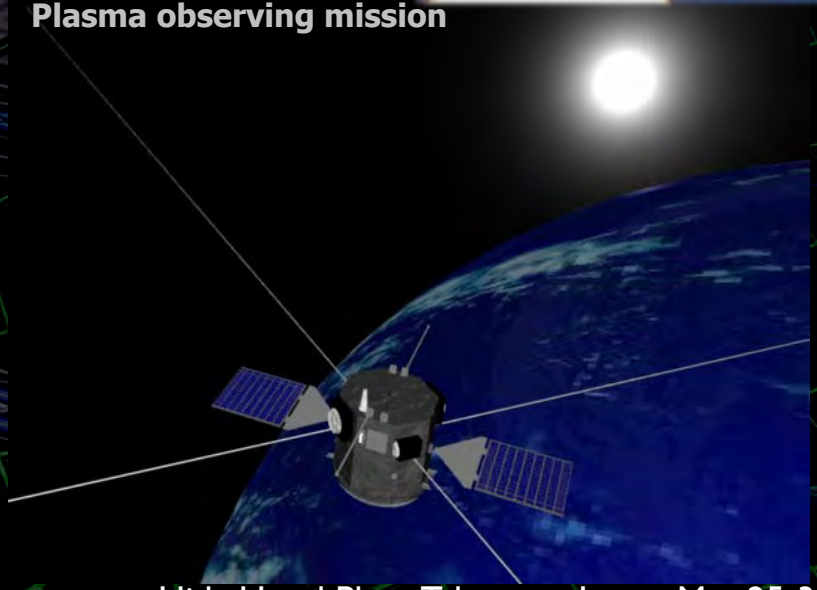
"At least 3 satellites in 5 years with Standard Bus + M-V follow-on rocket"

1st mission (2013): SPRINT-A /EXCEED
2nd mission (~2014/15) : SPRINT-B /ERG
3rd mission (~2016/17) : SPRINT-C? /TBD? ←cancelled
Call for proposal : 2013?

SPRINT-A /EXCEED
UV telescope mission



SPRINT-B /ERG
Plasma observing mission

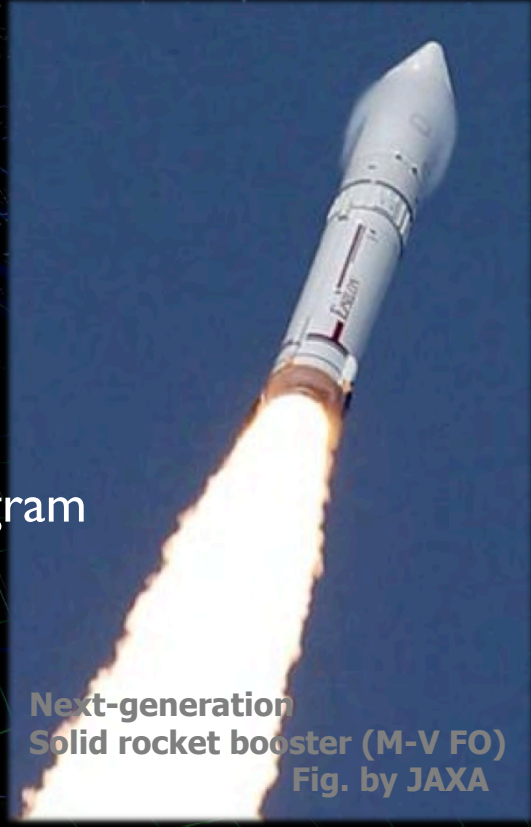


Mission status of DECIGO pathfinder

- JAXA's "Small science satellite series" program

  1st mission (2013): SPRINT-A /EXCEED
  2nd mission (~2014/15) : SPRINT-B /ERG

- JAXA's "small science mission using epsilon rocket" program
  - The program framework was changed:
    ~10 M$ payload mission to ~150 M$ full mission
  - AO from JAXA : December 2013
  - Deadline : End of February.
    - 7 mission proposals including DPF



DPF was dropped in the first down-selection (May)

Started discussions on the next strategy

Thinking back on DECIGO…

- DECIGO : Suggested in 2001
  Seto, Kawamura and Nakamura, *PRL87, 221103 (2001)*
- DPF : Suggested in 2005
  Ando, DECIGO workshop *(2005)*
- Good chance to reconstruct the strategy to DECIGO
  - Object of mission
  - Instrument design
  - Strategic demonstration of technologies

Summary

DECIGO : Rich Sciences !

- Very beginning of the Universe
- Dark energy, Dark matter
- Galaxy formation

DECIGO Pathfinder

- Mission proposal failed in selection
- Good chance to reconstruct the strategy to DECIGO

Started discussions on the next strategy