DECIGO

The Japanese Space Gravitational Wave Antenna

Kenji Numata

(Univ. of Maryland/NASA-GSFC)

For the Japanese DECIGO team

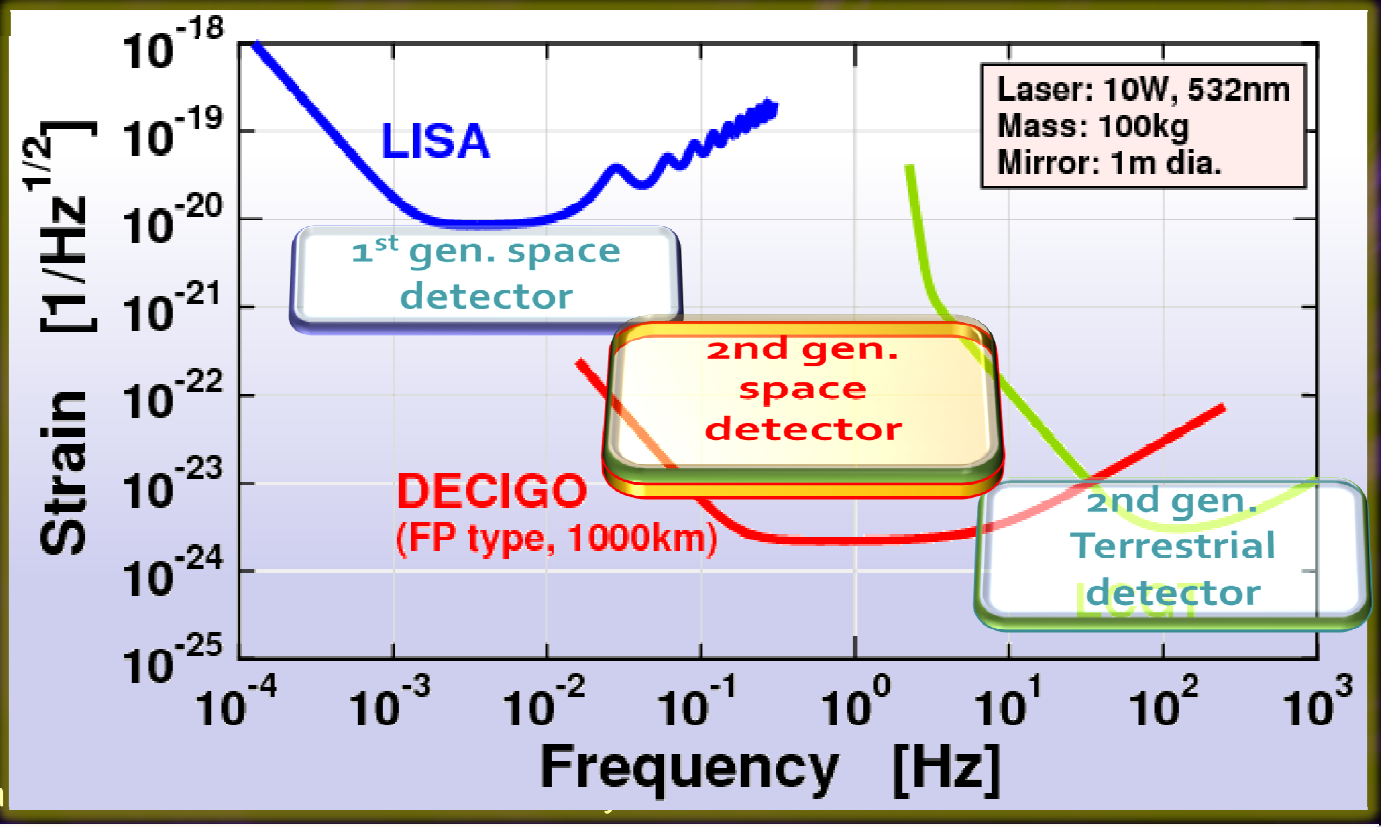
Seiji Kawamura, **Masaki Ando**, Takashi Nakamura, Kimio Tsubono, Takahiro Tanaka, Ikkoh Funaki, Naoki Seto, **Shuichi Sato**, Nobuyuki Kanda, Takeshi Takashima, Kunihito Ioka, Kazuhiro Agatsuma, Tomotada Akutsu, Tomomi Akutsu, Koh-suke Aoyanagi, Koji Arai, Yuta Arase, Akito Araya, Hideki Asada, Yoichi Aso, Takeshi Chiba, Toshikazu Ebisuzaki, Motohiro Enoki, Yoshiharu Eriguchi, Masa-Katsu Fujimoto, Ryuichi Fujita, Mitsuhiro Fukushima, Toshifumi Futamase, Katsuhiko Ganzu, Tomohiro Harada, Tatsuaki Hashimoto, Kazuhiro Hayama, Wataru Hikida, Yoshiaki Himemoto, Hisashi Hirabayashi, Takashi Hiramatsu, Feng-Lei Hong, Hideyuki Horisawa, Mizuhiko Hosokawa, Kiyotomo Ichiki, Takeshi Ikegami, Kaiki T. Inoue, Koji Ishidoshiro, Hideki Ishihara, Takehiko Ishikawa, Hideharu Ishizaki, Hiroyuki Ito, Yousuke Itoh, Shogo Kamagasako, Nobuki Kawashima, Fumiko Kawazoe, Hiroyuki Kirihara, Naoko Kishimoto, Kenta Kiuchi, Shiho Kobayashi, Kazunori Kohri, Hiroyuki Koizumi, Yasufumi Kojima, Keiko Kokeyama, Wataru Kokuyama, Kei Kotake, Yoshihide Kozai, Hideaki Kudoh, Hiroo Kunimori, Hitoshi Kuninaka, Kazuaki Kuroda, Kei-ichi Maeda, Hideo Matsuhara, Yasushi Mino, Osamu Miyakawa, Shinji Miyoki, Mutsuko Y. Morimoto, Tomoko Morioka , Toshiyuki Morisawa, Shigenori Moriwaki, Shinji Mukohyama, Mitsuru Musha, Shigeo Nagano, Isao Naito, Noriyasu Nakagawa, Kouji Nakamura, Hiroyuki Nakano, Kenichi Nakao, Shinichi Nakasuka, Yoshinori Nakayama, Erina Nishida, Kazutaka Nishiyama, Atsushi Nishizawa, Yoshito Niwa, Masatake Ohashi, Naoko Ohishi, Masashi Ohkawa, Akira Okutomi, Kouji Onozato, Kenichi Oohara, Norichika Sago, Motoyuki Saijo, Masaaki Sakagami, Shin-ichiro Sakai, Shihori Sakata, Misao Sasaki, Takashi Sato, Masaru Shibata, Hisaaki Shinkai, Kentaro Somiya, Hajime Sotani, Naoshi Sugiyama, Yudai Suwa, Hideyuki Tagoshi, Kakeru Takahashi, Keitaro Takahashi, Tadayuki Takahashi, Hirotaka Takahashi, Ryuichi Takahashi, Ryutaro Takahashi, Takamori Akiteru, Tadashi Takano, Keisuke Taniguchi, Atsushi Taruya, Hiroyuki Tashiro, Mitsuru Tokuda, Masao Tokunari, Morio Toyoshima, Shinji Tsujikawa, Yoshiki Tsunesada, Ken-ichi Ueda, Masayoshi Utashima, Hiroshi Yamakawa, Kazuhiro Yamamoto, Toshitaka Yamazaki, Jun'ichi Yokoyama, Chul-Moon Yoo, Shijun Yoshida, Taizoh Yoshino

Abstracts

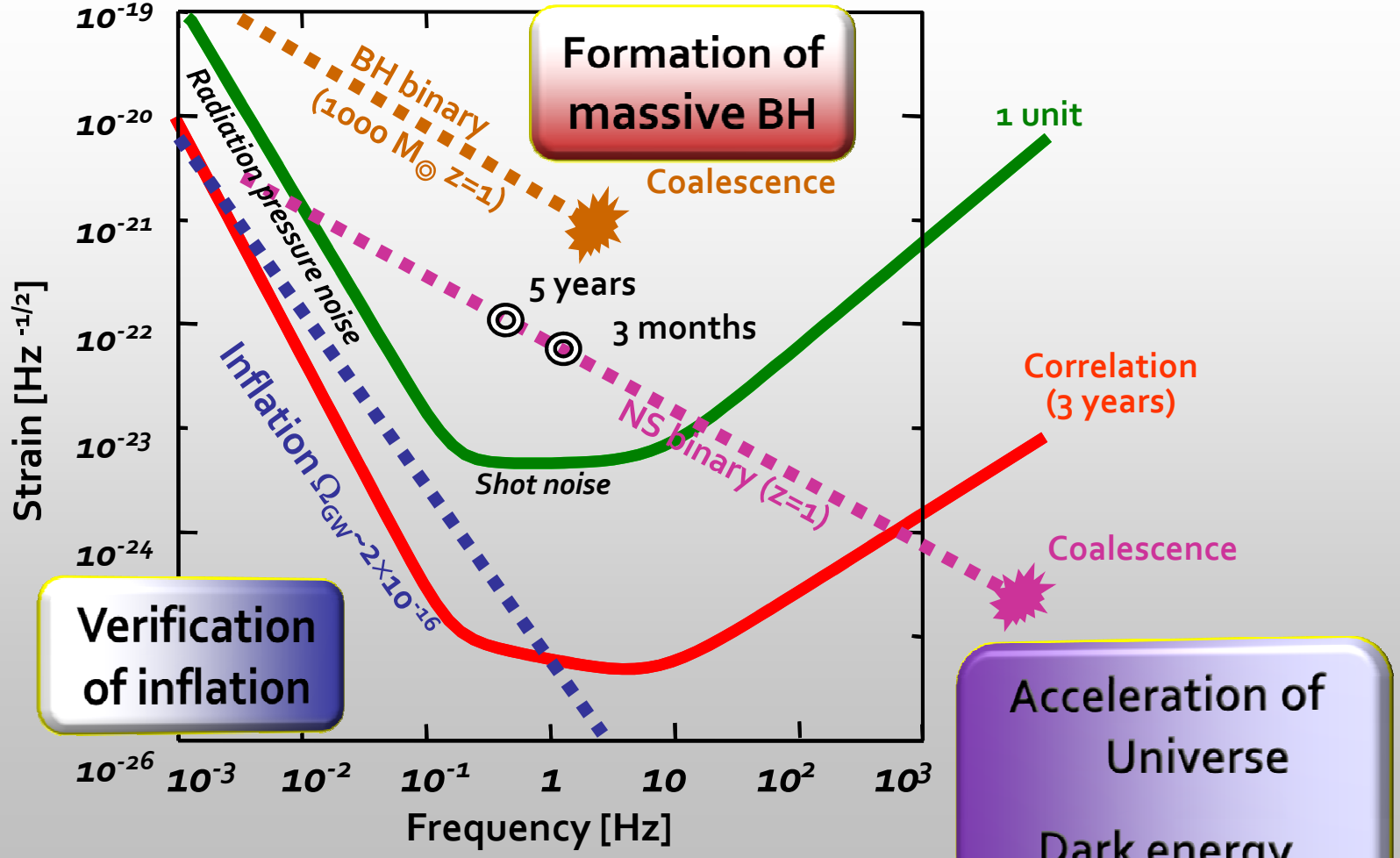
- Japanese activities for space gravitational wave detector
- DECIGO
  - 0.1~10Hz gravitational wave
  - Ultimate sensitivity : ~10^{-24}/rtHz
  - Detection of GW from inflation
    - Launch timescale : 2024?
- DECIGO PathFinder (DPF)
  - Now in Pre-phase A
  - Demonstrates DECIGO technologies
  - Could detect GW from galactic center
    - Launch timescale : 2012

Motivation for DECIGO

- **DECI-hertz Interferometer Gravitational Wave Observatory**
  - Seto, Kawamura and Nakamura, PRL **87** 221103 (2001)
  - Kawamura, et al., CQG **23** S125-S131 (2006)
  - Bridges the gap between LISA and terrestrial detector
  - Low confusion noise : extremely high sensitivity

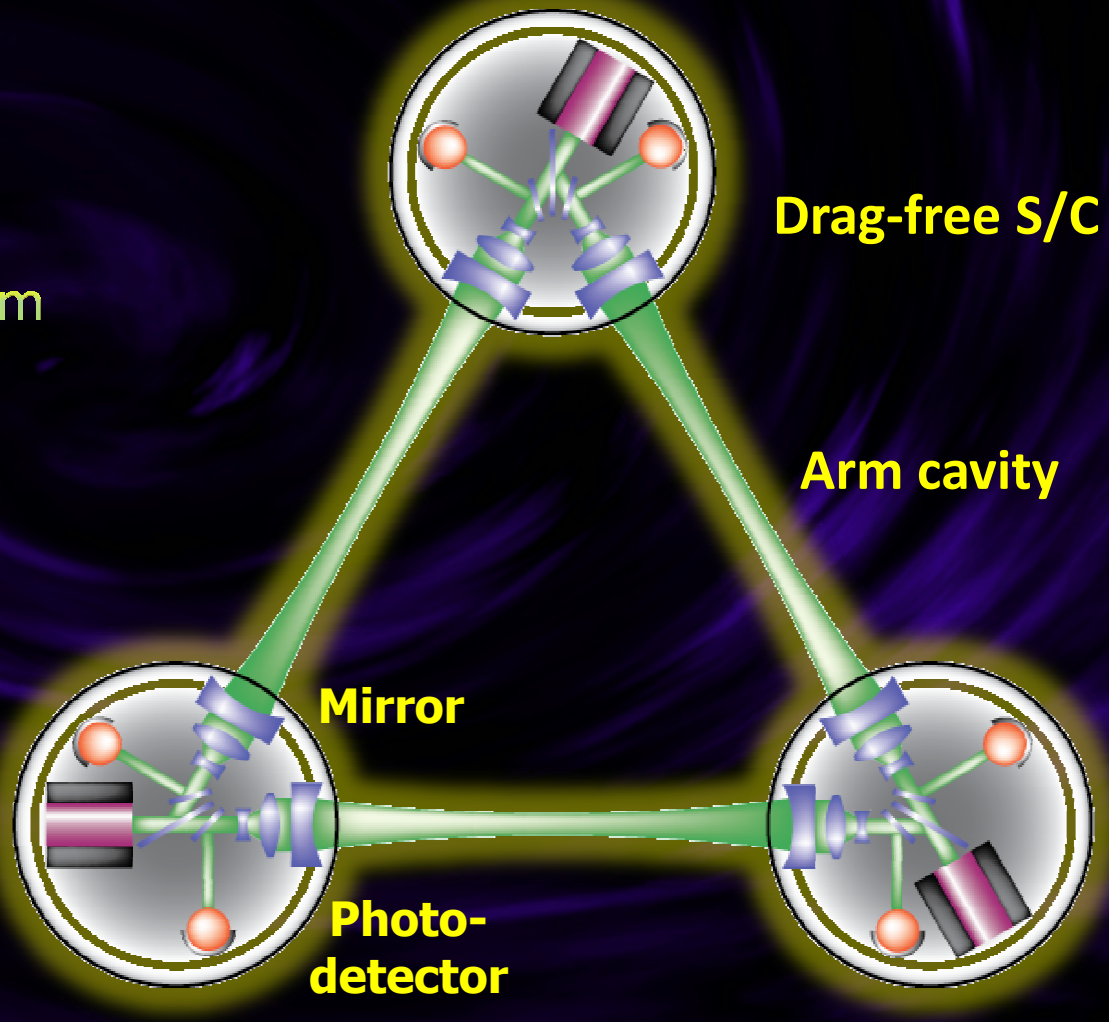


DECIGO Science Case



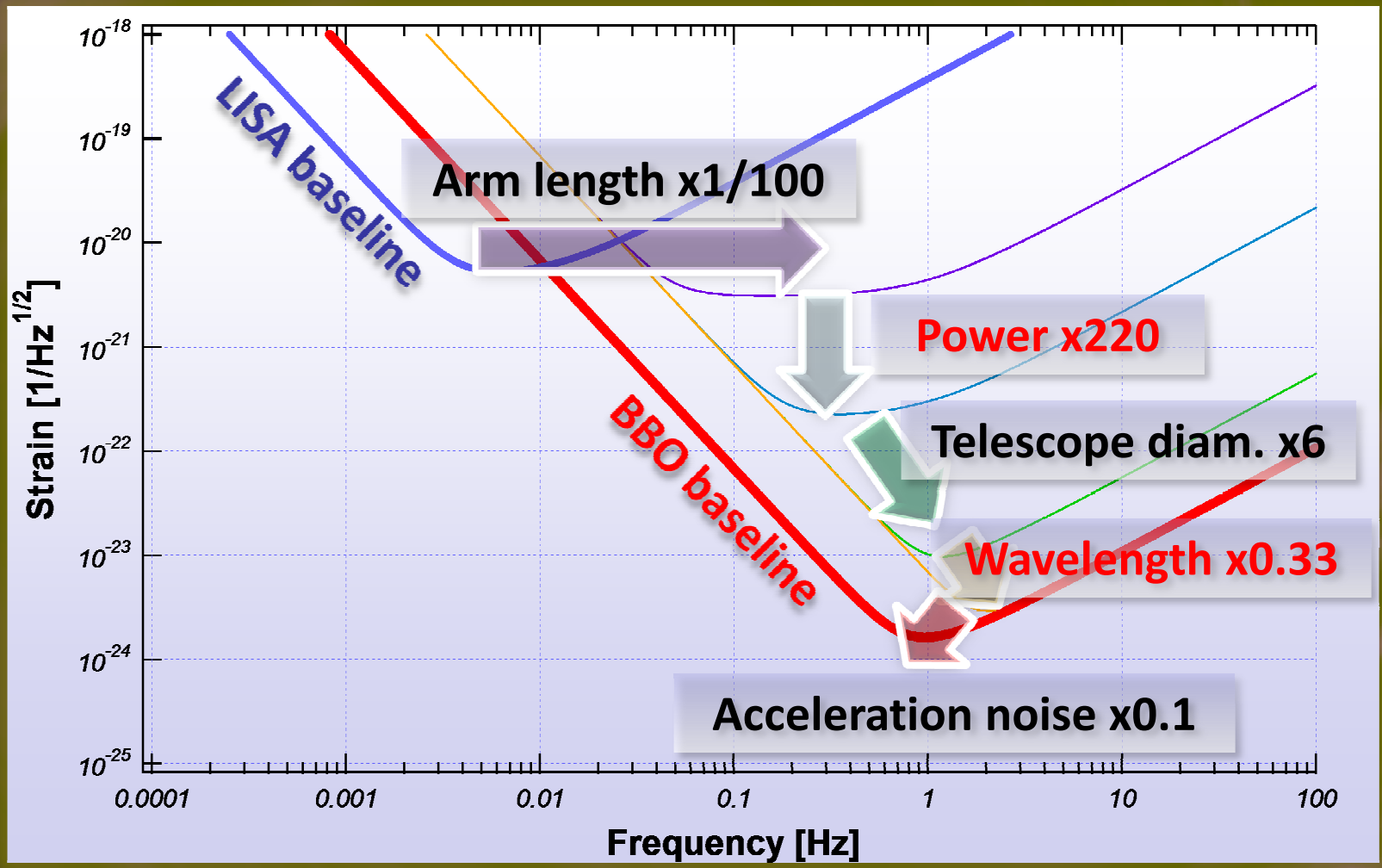
Pre-Conceptual Design

- **Differential Fabry-Perot interferometer**
  - Arm length: 1000 km
  - Mirror diameter: 1 m
  - Mirror mass: 100 kg
  - Laser wavelength : 532 nm
  - Laser power: 10 W
  - Finesse: 10
  - Drag free spacecrafts
  - 3 interferometers



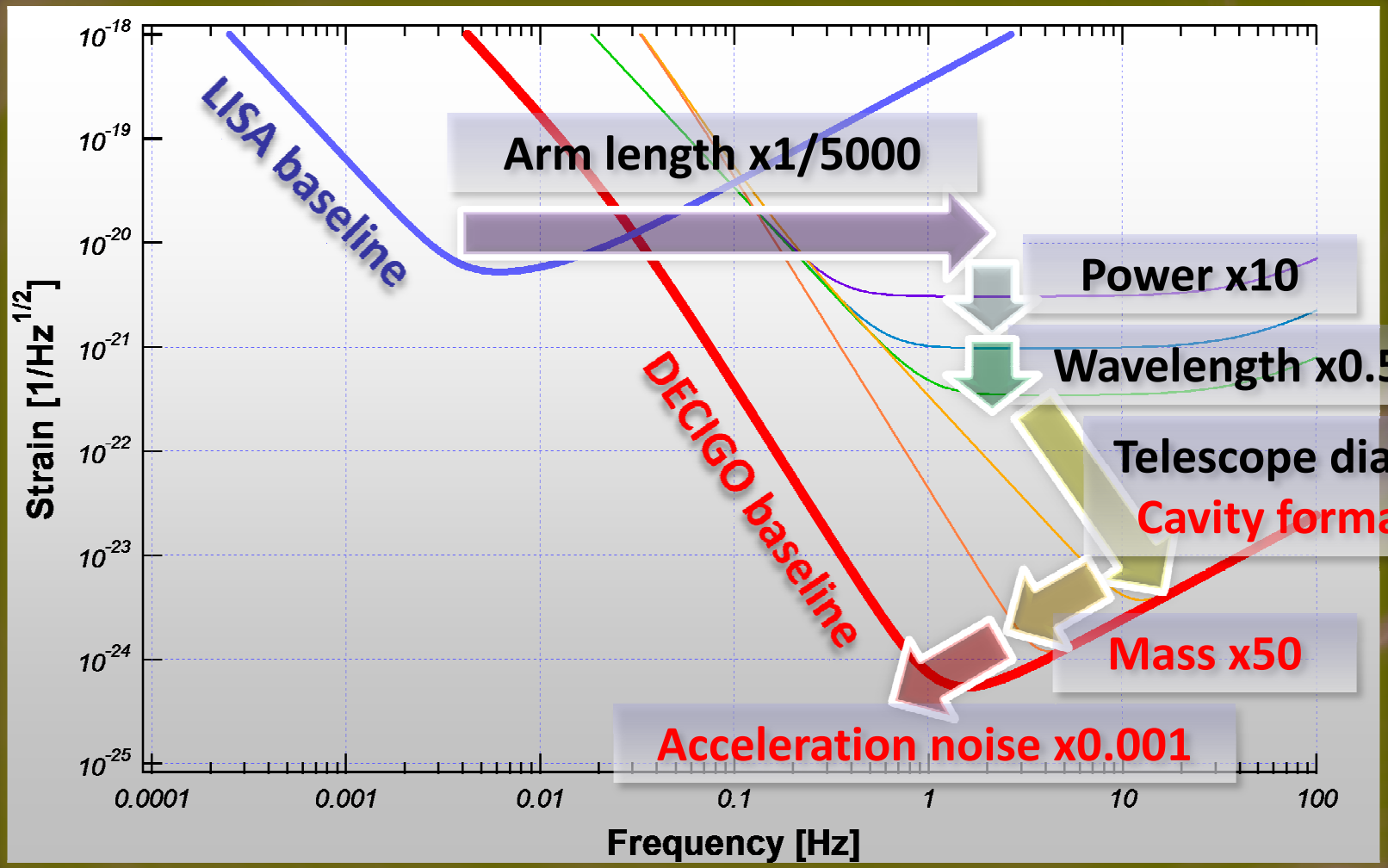
Sensitivity Improvement

- Optical transponder approach (e.g. BBO)



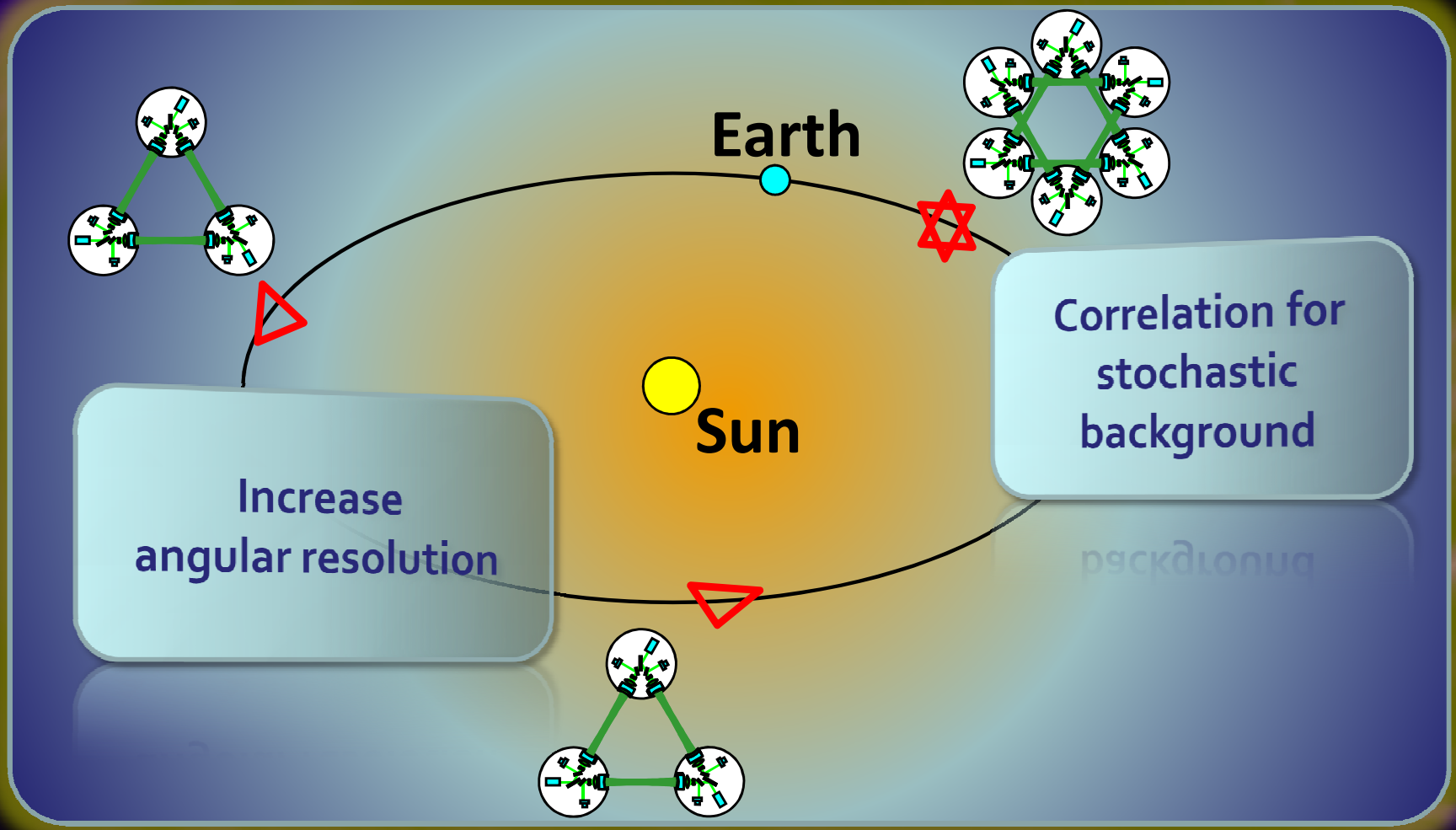
Sensitivity Improvement

- Cavity approach (e.g. DECIGO)



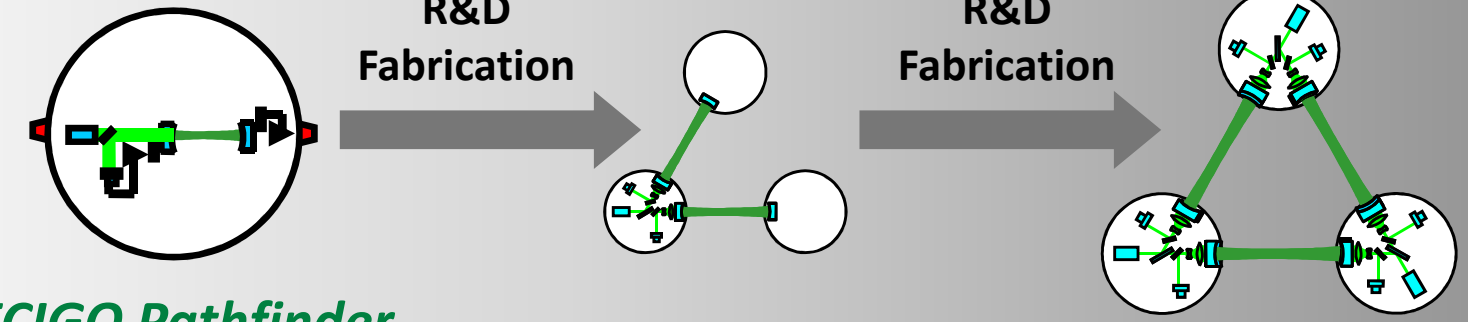
Orbit and Constellation

- **Ultimate DECIGO**
  - 4 units, Sun-synchronous orbits



DECIGO Roadmap

	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Mission	R&D Fabrication → *DECIGO Pathfinder (DPF)*								R&D Fabrication → *Pre-DECIGO*						R&D Fabrication → *DECIGO*					
Objectives	Test of key technologies								Detection of GW w/ minimum spec. Test FP cavity between S/Cs						Full GW astronomy					
Scope	1 S/C 1 arm cavity								3 S/Cs 1 interferometer						3 S/Cs, 3 interferometers 3 or 4 units					

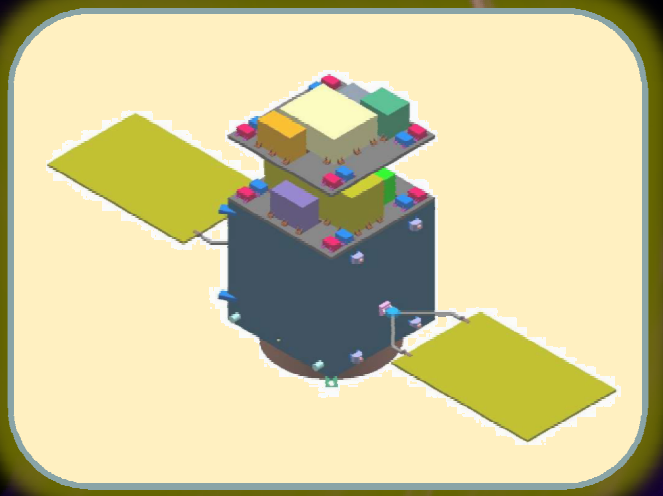


Current Status of DECIGO

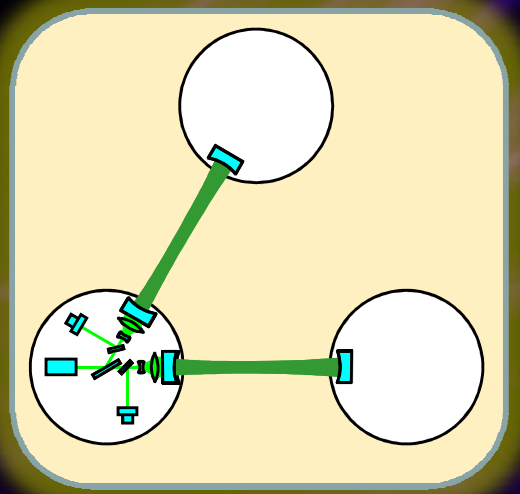
- DECIGO working group
  - 140 members from 50 institutes
    - Had 6 workshops by now
    - DECIGO-LISA joint workshop planned on Nov. 2008 in Japan
  - Fixing conceptual design
    - Interferometer trade studies
    - Mission design studies
    - Science requirement documents
  - Efforts concentrated on DECIGO PathFinder (DPF)
    - DPF technical meeting held bi-monthly
    - DPF now in Pre-phase A

Planned Pathfinder Missions

- **1st: DECIGO PathFinder (DPF)**
  - Key technology demonstration
    - With drag free operation in single S/C
    - Noise level: 10^9 times larger than DECIGO
    - R&D budget allocated
    - Development with earthquake/geophysics research labs

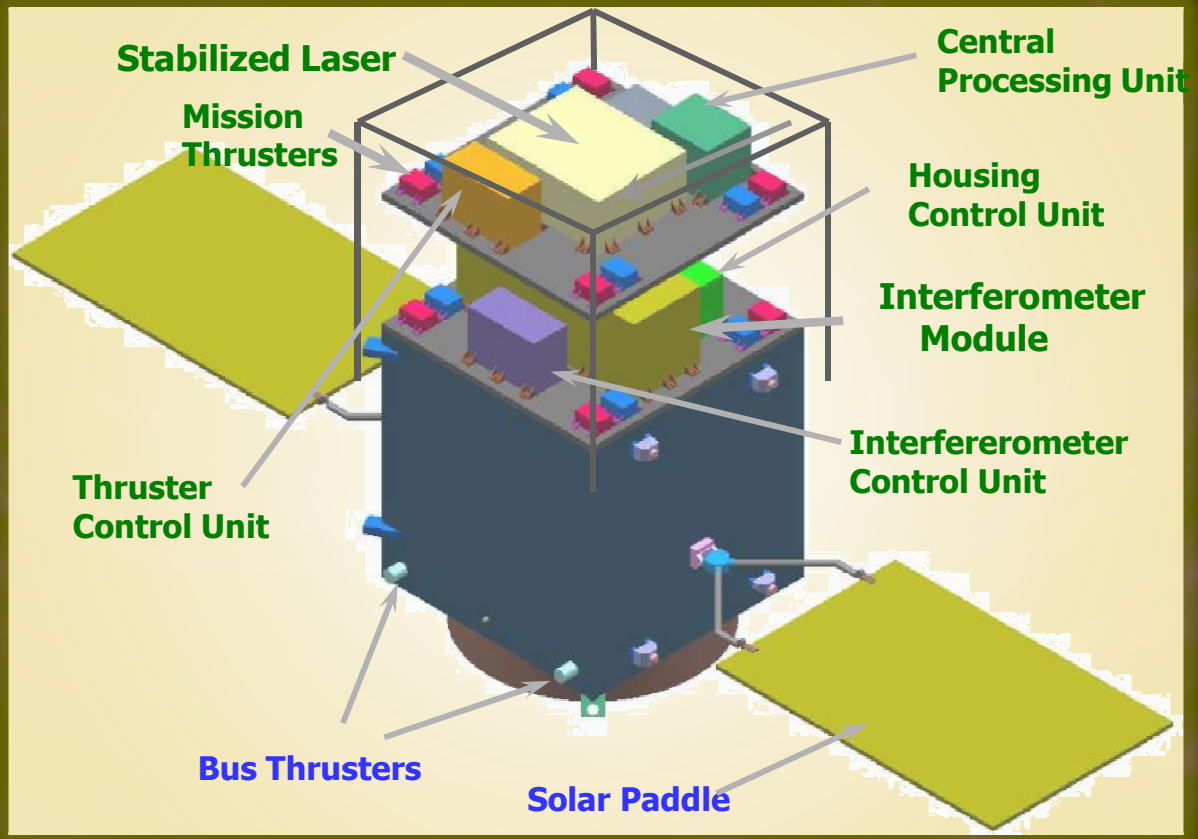


- **2nd: pre-DECIGO**
  - Gravitational wave observation
    - with formation flight
    - Noise level: 10^5 times larger than DECIGO
    - Still conceptual



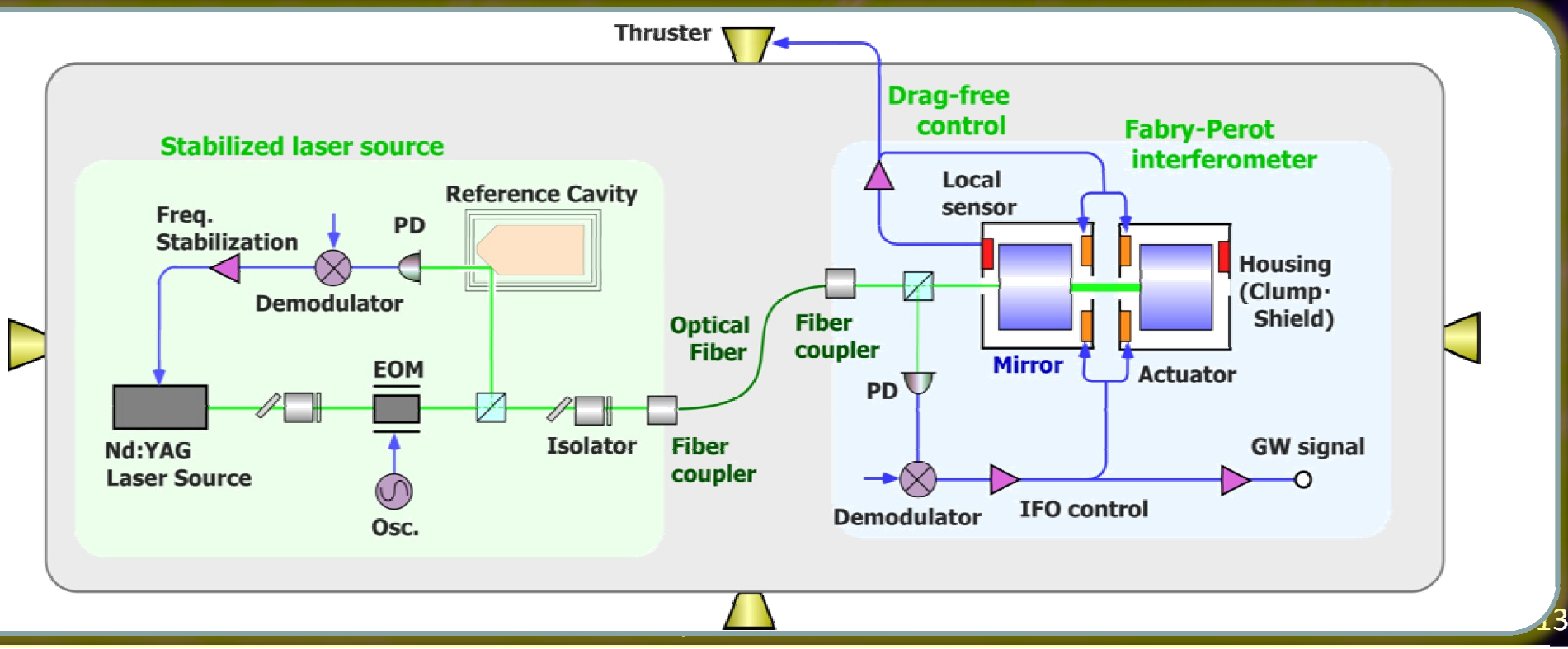
DPF Satellite

- **DPF Payload**
  - Interferometer and test masses
    - Size : 900mm cube
    - weight: 100kg
    - Power: 200W
    - 16 mission thrusters
    - SpW
- **Satellite Bus**
  - Standardized system
    - Size: 900mm cube
    - Weight: 200kg
    - Low-Earth, Sun-synchronous orbit



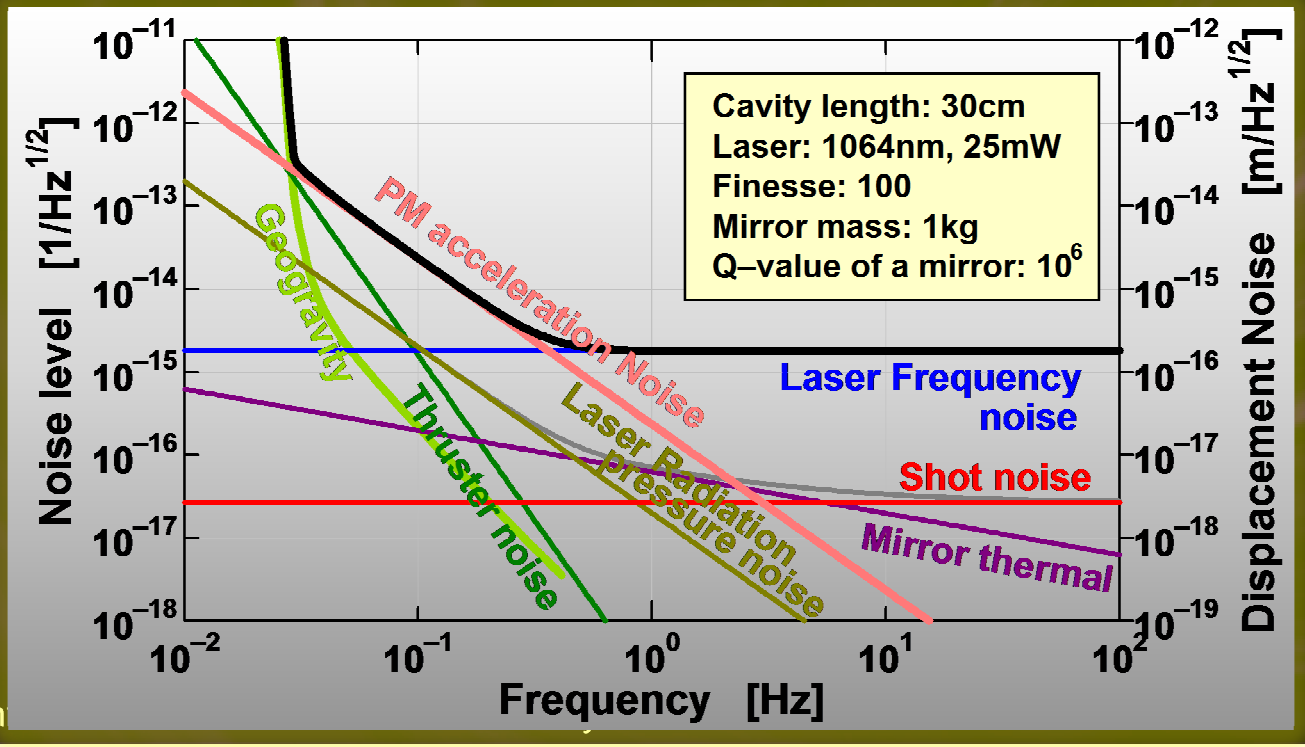
DPF Payload Concept

- Fabry-Perot interferometer
  - Arm length: 30cm, finesse: 100
    - Provides sensitivity to gravitational wave and gravitational gradient
  - Laser: 25mW Nd:YAG
    - Frequency stabilization with external cavity



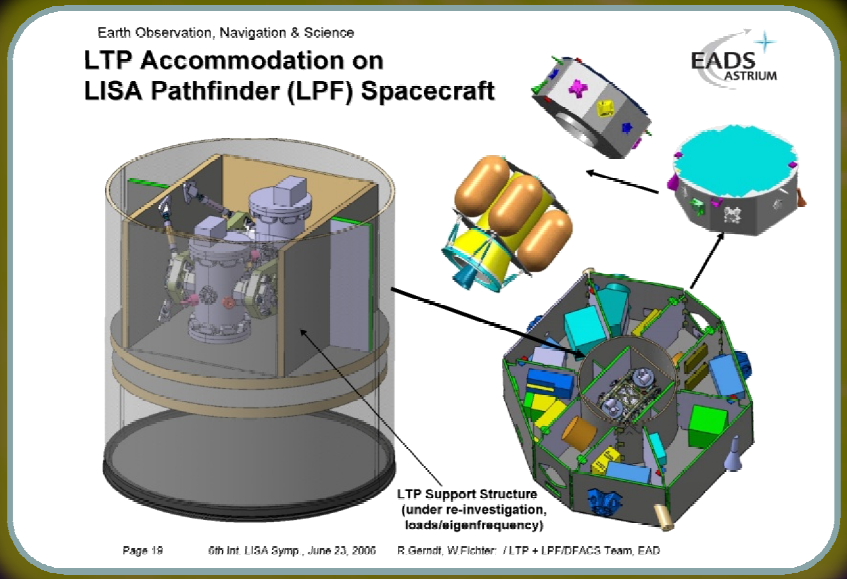
DPF Sensitivity

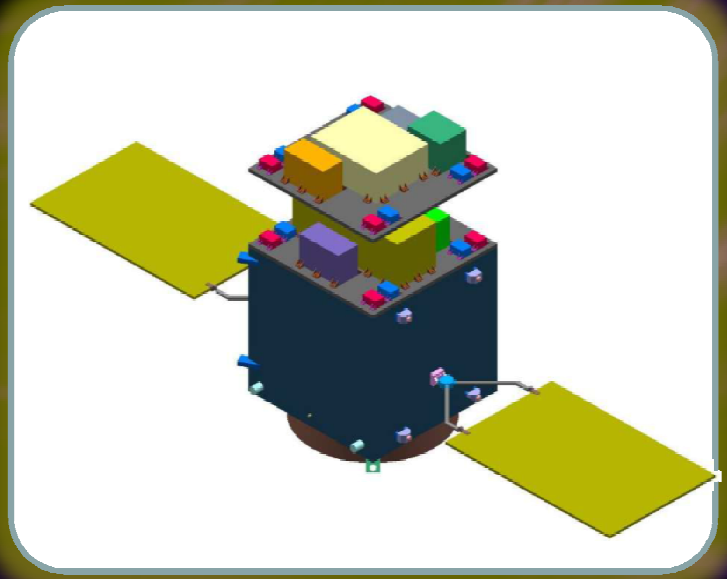
- **Technical noise sources**
  - Laser frequency noise & test mass acceleration noise
- **Science signals**
  - Gravitational wave from galactic center? (e.g. IMBH inspiral)
  - Earth's gravity field (gradient)



LISA Pathfinder and DPF

	LPF	DPF
Purpose	Demonstration for LISA	Demonstration for DECIGO GW observations
Launch	2010	2012
Weight	2000kg	300kg
Orbit	Halo orbit around L1	SSO altitude 500km
Interferometer	Mach-Zehnder	Fabry-Perot

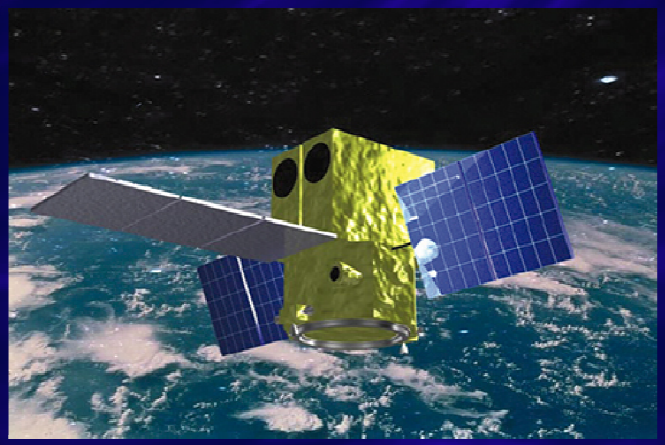




DPF Launch Opportunity

- **JAXA's small satellite program**
  - Launch 3 small satellites by 2015
    - Next-generation solid rocket booster
    - 'Standard bus system'
      - Bus weight : ~200kg
      - 3-axes attitude control
  - Selected Missions
    - 1st mission (2011): TOPS (Planetary science)
    - 2nd and 3rd mission
      - Selected by 2009 March
    - **DPF is one of 15 candidate missions.**
      - DPF selected as one of 5 important missions

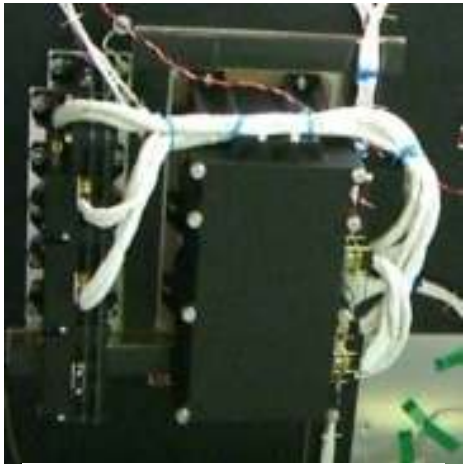
M-V follow-on



TOPS

Current Status of DPF

- **Brief History**
  - 2005 Jan. Proposal I submitted
    - Resulted in SWIMμυ module on SDS-1
      - Small Demonstration Satellite
    - Small GW resonant detector mission
      - Planned launch: FY2008
      - Under environmental testing
  - 2006 Nov. Proposal II submitted
    - DECIGO pathfinder (DPF)
  - 2007 Aug. Selected for Pre-phase A study
    - R&D costs funded
  - Now submitting Phase A proposal



SWIM fixed to SDS-1 satellite
(July 11, 2008)

Summary

- Space gravitational-wave missions in Japan
- DECIGO
  - Open new GW window in 0.1~10Hz
  - Mission formulation study started
    - Target launch date: 2024?
- DECIGO Pathfinder (DPF)
  - Now under Pre-phase A study
    - For JAXA's small scale satellite program
    - Target launch opportunity: 2012