Ando Lab Vision 2017

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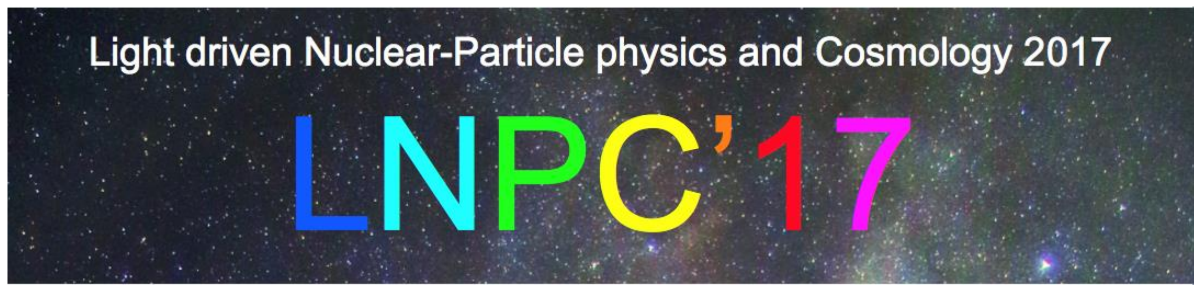
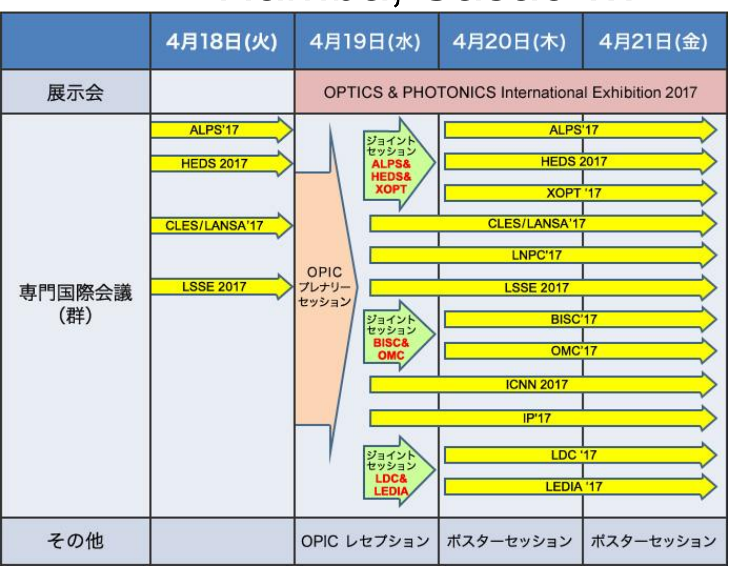
LNPC'17

- One of the 12 conferences in OPIC2017
  co-located with OPIE'17
- LNPC'17 was (almost) only the one focused on fundamental science, theory and experiment (first one to have in OPIC2017)
- People I saw
  Arai, Kokuyama
  Somiya, Tasumi
  Hazumi, Asai
  Namba, Sasao …





OPTICS & PHOTONICS International Congress
OPIC
OPTICS & PHOTONICS
International Congress 2017

Report

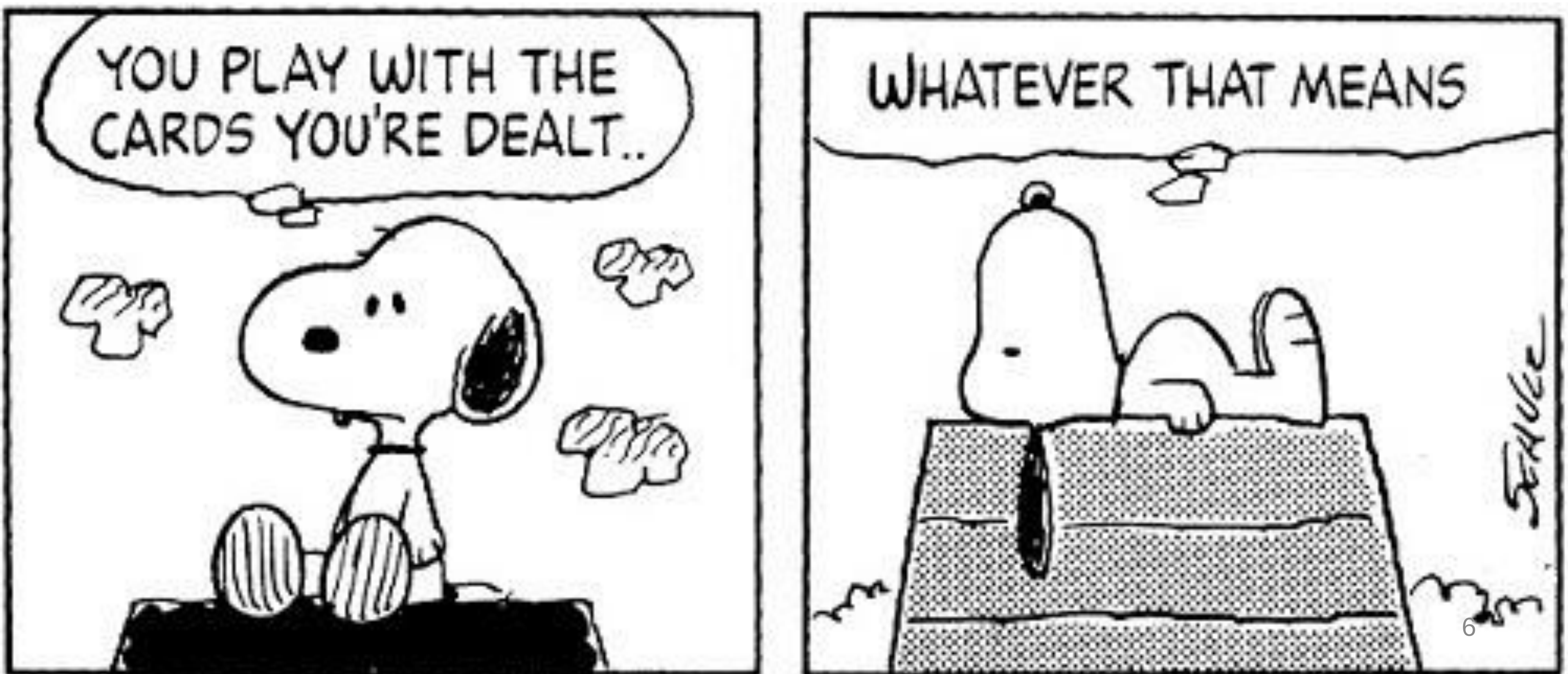
- Plenary talk on Advanced LIGO by Koji Arai
  question on Voyager upgrade status, can interferometers really measure GWs?

- LNPC was mainly on QED, vacuum birefringence, high-intensity lasers, axion, etc.
- Lorentz invariance talk was “unexpected”
  but many questions: Why silicon? Any vibration isolation? Temperature fluctuation of silicon? Possibility of subtracting something else by magnetic noise subtraction? Where does anisotropy comes from? Something to do with vacuum? Polarization dependence of c? Location dependence of anisotropy?
- Attended LNPC on 19th PM, 20th AM
- Liquid Instruments, Okamoto Optics, Hamamatsu Photonics, Thorlabs, Herz, NAOJ (TMT), etc.


松竹梅

Ando Lab Vision 2017

- Directs what we should do based on technology we have and science we are interested

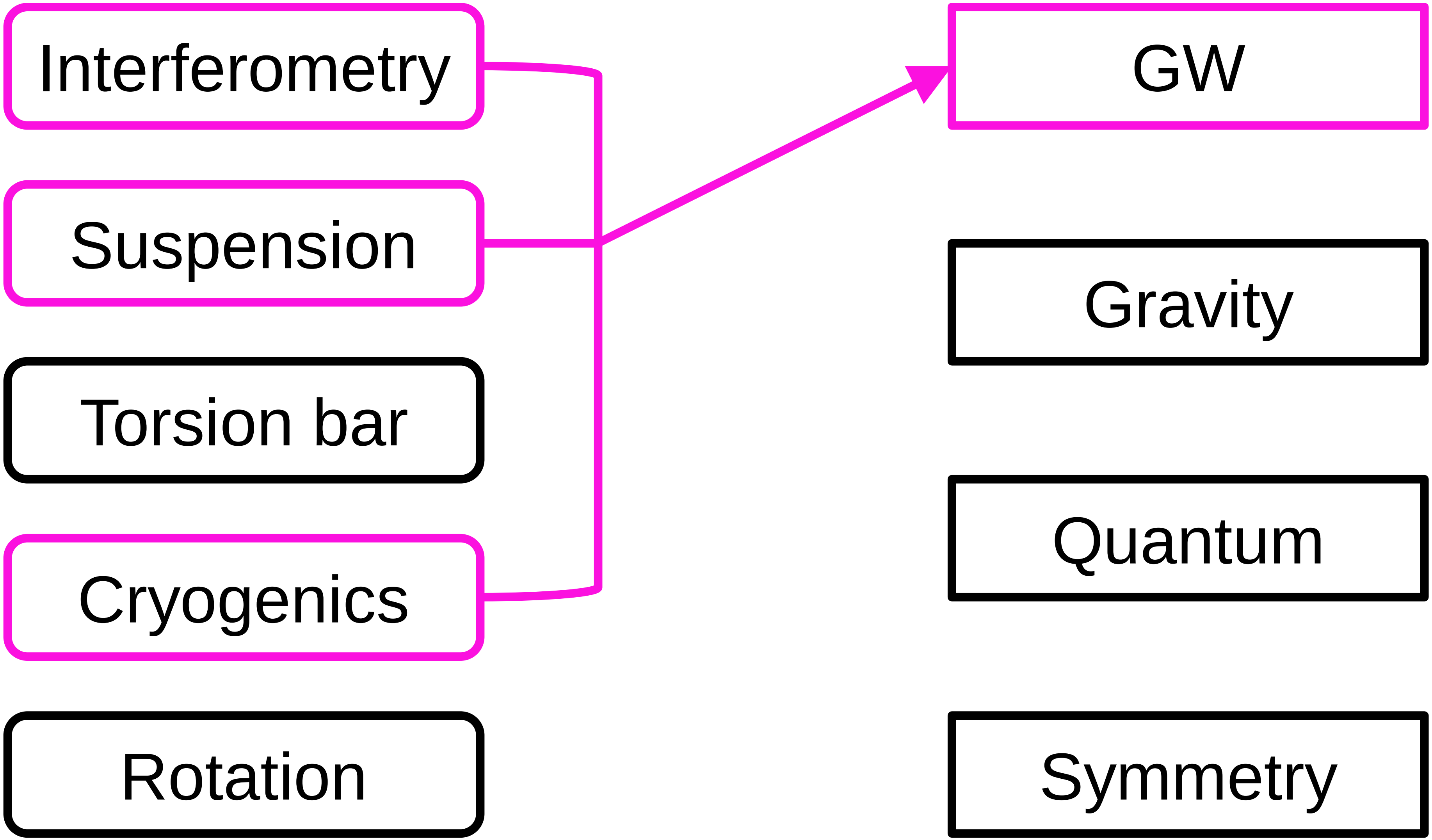


Technology and Scientific Interests

- Interferometry
- Suspension
- Torsion bar
- Cryogenics
- Rotation

- GW
- Gravity
- Quantum
- Symmetry

KAGRA


Interferometry
Suspension
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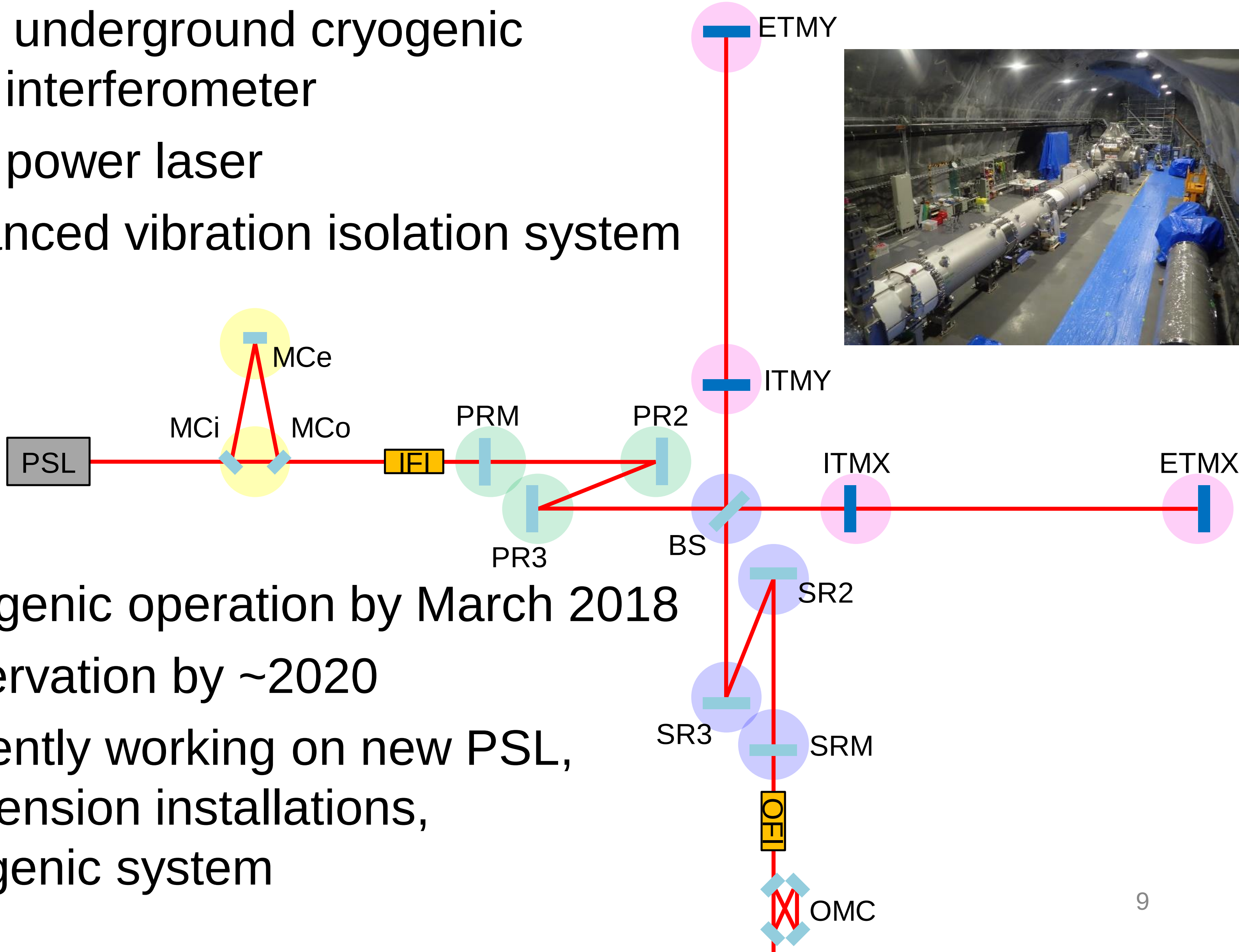
GW
Gravity
Quantum
Symmetry

KAGRA

- 3-km underground cryogenic RSE interferometer
- High power laser
- Advanced vibration isolation system



- Cryogenic operation by March 2018
- Observation by ~2020
- Currently working on new PSL, suspension installations, cryogenic system

Research Topics Available 1

- IFO commissioning [Kamioka] EXP

  first km-scale cryogenic IFO in March 2018, bKAGRA within few years
  great timing, no dedicated person yet; you can be the one

- High power laser development [Asano/Toyama?] EXP

  coherent addition of fiber amps (more modern than aLIGO)
  intensity and frequency stabilization
  deformable mirror and wavefront correction using genetic algorithm
  mirror deformation by heat estimation using Kalman filter
  not needed for KAGRA for ~5 years; half-independent from the project
  no dedicated person yet

- ISC modeling [Hongo] COM

  simulate IFO and design signal extraction and controls scheme
  design RF sideband generation scheme
  (different from aLIGO since we use AM instead of 3f)
  green lock and frequency stabilization modeling
  (more simple green lock than aLIGO)

Research Topics Available 2

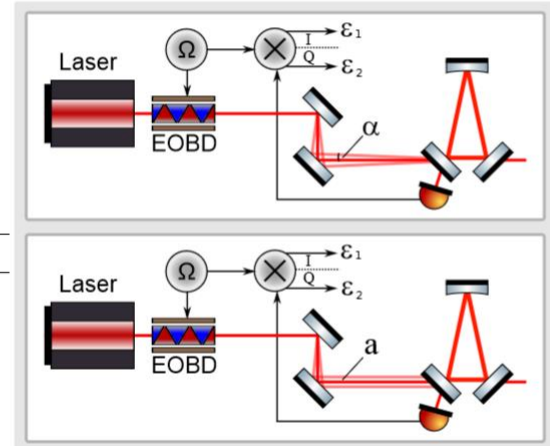
- OMC development [Ookayama/Hongo] EXP
  conceptual design is done, but actual instrumentation including PDs and QPDs not yet
  monolithic optical ring cavity
  also suspension and actuation
  not needed for KAGRA within ~5 years
- Detector Characterization [Hongo/Kamioka] COM
  identify causes of lock losses, glitch study, data quality check
  Newtonian noise estimation
  few experimentalists working on this
  underground data is interesting for whole GW community
  great chance to work with data analysis and statistics people
- Calibration [Hongo/Kamioka] COM
  h(t) generation from IFO signal
  relationship between calibration accuracy (amplitude, phase) and parameter estimation error
  directly linked to science
  few students working on this, much support from staff

Research Topics Available 3

- 300m filter cavity [Mitaka] EXP
  using TAMA facility and AEI squeezer
  TAMA is old, make new suspensions, LabView system
  no dedicated student yet
  great chance to work with LVC people (LMA etc.)
- Modern controls [Hongo] COM/EXP
  apply modern controls to suspension local damping, global control, ISC
  great chance to work with experts in Department of Engineering
- New alignment/mode-matching scheme [Hongo] COM/EXP
  new idea needed
  for example, https://dcc.ligo.org/LIGO-P1700028
- KAGRA+ designing, prototyping [Hongo] COM/EXP
  20 K silicon? better cryogenic suspension design?
  automate suspension thermal noise calculation
  optimization of sensitivity using particle swarm, genetic algorithm, simulated annealing, etc.
  coating, absorption, mechanical loss research

RF Jitter Modulation for ASC

- RF pre-modulation instead of AF dithering



Research Article | Applied Optics 1

Alignment sensing for optical cavities using radio frequency jitter modulation

P. Fulda[1], D. Voss[1], C. Mueller[1], L. F. Ortega[1], G. Ciani[1], G. Mueller[1], and D. B. Tanner[1]

[1] *University of Florida , Gainesville, Florida 32611, USA*
[*] *Corresponding author: pfulda@phys.ufl.edu*

Compiled February 19, 2017

Alignment sensing is often required in precision interferometry applications such as Advanced LIGO in order to achieve the optimum performance. Currently favored sensing schemes rely on the use of two separate RF quadrant photodetectors and Gouy phase telescopes to determine the alignment of a beam relative to an optical cavity axis. In this paper we demonstrate and alternative sensing scheme that has potential advantages over the currently standard schemes. We show that by using electro-optic beam deflectors to impose RF jitter sidebands on a beam it is possible to extract full alignment signals for two in-line optical cavities from just one single-element photodetector in reflection of each cavity.

OCIS codes: *220.1140, 040.5160, 140.3295, 140.4780, 120.3180, 000.2780*

http://dx.doi.org/10.1364/ao.XX.XXXXXX

LIGO-P1700028

Tabletop vs Big Project

- You might have some concerns for jumping into a big project like KAGRA
- I had some interviews with people working on other big projects

MY

- 現場や研究所はやはりプロジェクトを優先しがち。
- 指導教員と現場で指導体制があいまいになることも起こりがち。
- 一部の装置を学生に任せる、スタッフは面倒を見る。
- 装置開発でも論文は書けるし、書く。
- やはり現場に行かないと最先端の研究はできない。
- 現場での指導意識の改革を進めていくしかないのでは？
- 立ち上げ期は苦労するが、人は残る。その後が全然残れなくて大変。

KI

- サイトに学生を呼ぶ仕組みを変えるべき。3ヶ月程度いないとまとまった仕事を与えられない。シフトコールではなく名指しで呼ぶ。
- サイトで働く人に指導する余裕が必要。学生を優先させてプロジェクトを遅らせる決断もたまには必要。
- KAGRAは小規模なのですぐに中心的人物になれるメリットがある。
- テーブルトップ実験の方が有利ではない。サイエンスは大型実験にある。
- 論文が書けなくても大型実験で名を上げてコネで残っていける。
- サイトでの車や宿泊でもっとサポートできないか？　サイトカーを通勤に使っていいようにするとか。

KA

- KAGRAに参加すれば必ず貢献できる。
- KAGRAでもLIGOでもやっていることは同じで最先端。KAGRAで活躍すればLIGOの目にもとまる。
- テーブルトップ実験から、すぐに大型プロジェクトに参加するのは容易ではない。学生のうちから参加することのメリット。
- 会社に就職する際もKAGRAはメリット。つぶしが効く。
- 神岡に呼ぶ時は、この人に来てもらってこれをしてもらいたいと具体的に呼ぶ。
- 神岡では必ず修論/博論を書かせる。
- お試しで数ヶ月行く。

SA

- 学生を労働力のように扱ってもだめ。やりかたが下手。
- 修士と博士で2回、テーブルトップか大型か選択するチャンスがある。
- テーブルトップで博論は取れない。大型の方が安全。
- 解析だけではポスドク以降続かないので、装置開発をやらせる。
- 大型やりたい人も、修士の間は長期出張させない。本郷で解析や装置開発をやらせる。
- 自分の考えた実験は(実際はつまらなくても)楽しい。学生をだましてモチベーションを上げるのも上の仕事。

TN

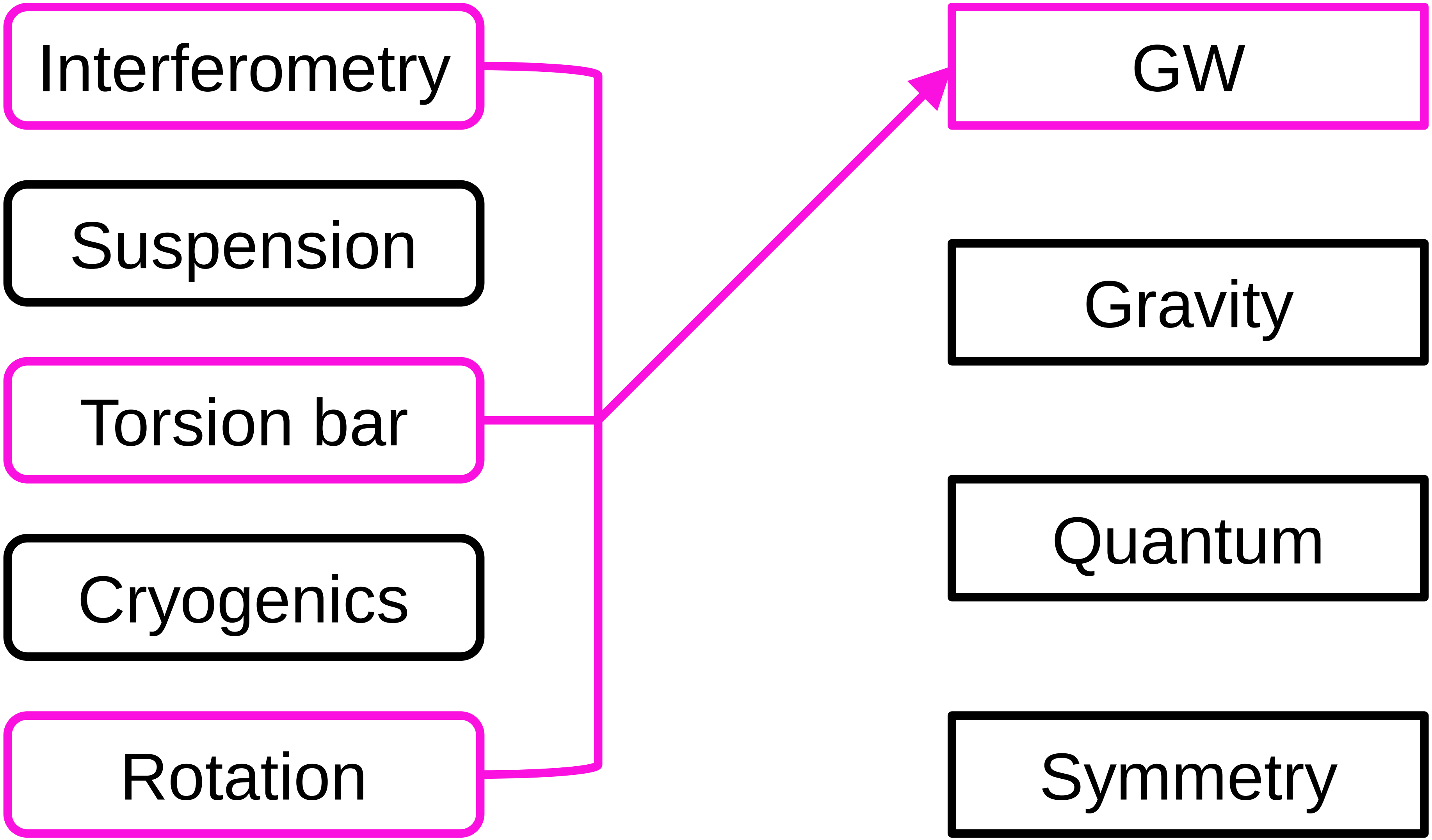
- テーブルトップ実験やりたい学生が多くて困るくらい。
- テーブルトップ実験をやると楽しいから大型なんてやりたくなくなる。
- 人によって向き不向きがある。
- 大型実験のインストール期は学生がほとんど修士までしか残らなくて大変だったらしい。

In Summary?

- Tabletop experiments
  often fun but could be risky
- Big projects
  almost guaranteed science
  but could be tough

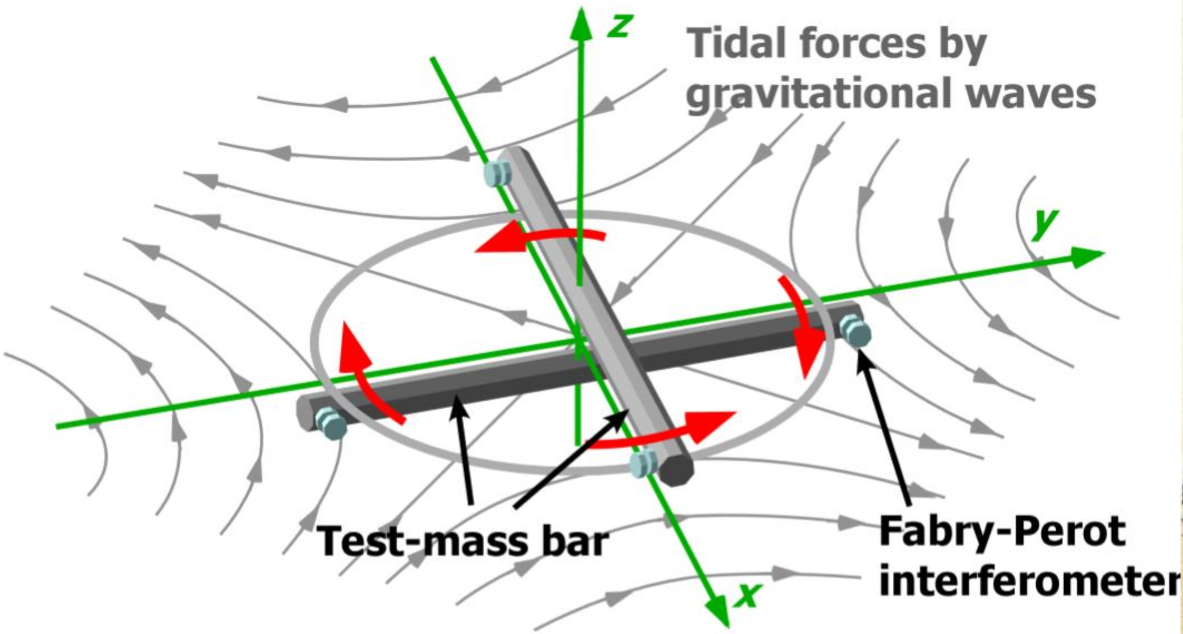
- My suggestions
  - develop basic skills before going to the site
  - stay more than 1 month, not few days
    (lodge available, travel and per diem provided)
  - I will visit the site more often if you are there
  - don't be too picky

Rotating TOBA



Rotating TOBA

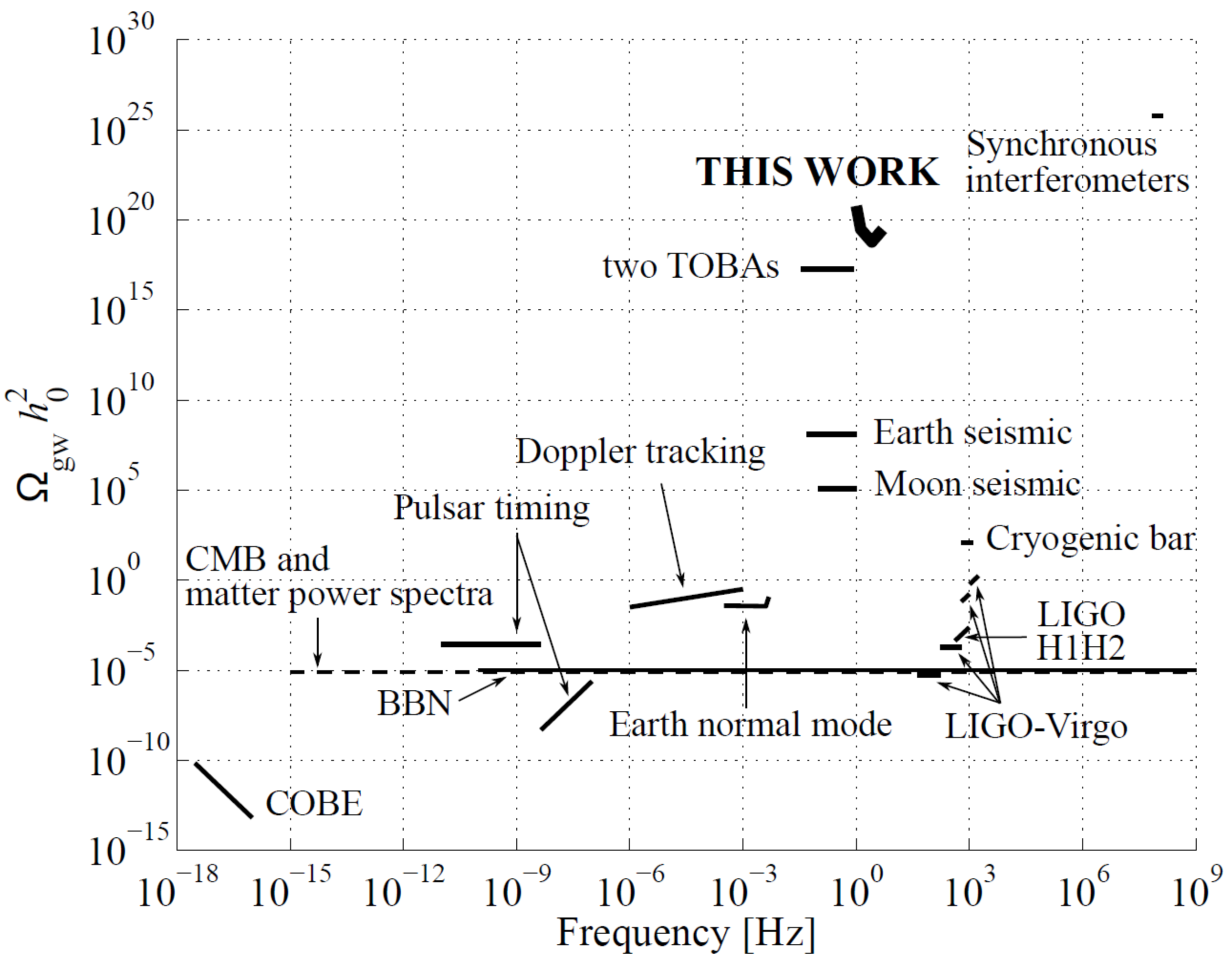
- Rotate TOBA to up convert GW signal
- Very low frequency GW search with noise level at higher frequency will be possible
- GW background,
  super massive BH,
  intermediate mass BH,
  white dwarf binary



Stochastic GW Background

- Lowering the observation frequency by 10 is equivalent to lowering the noise by 1000

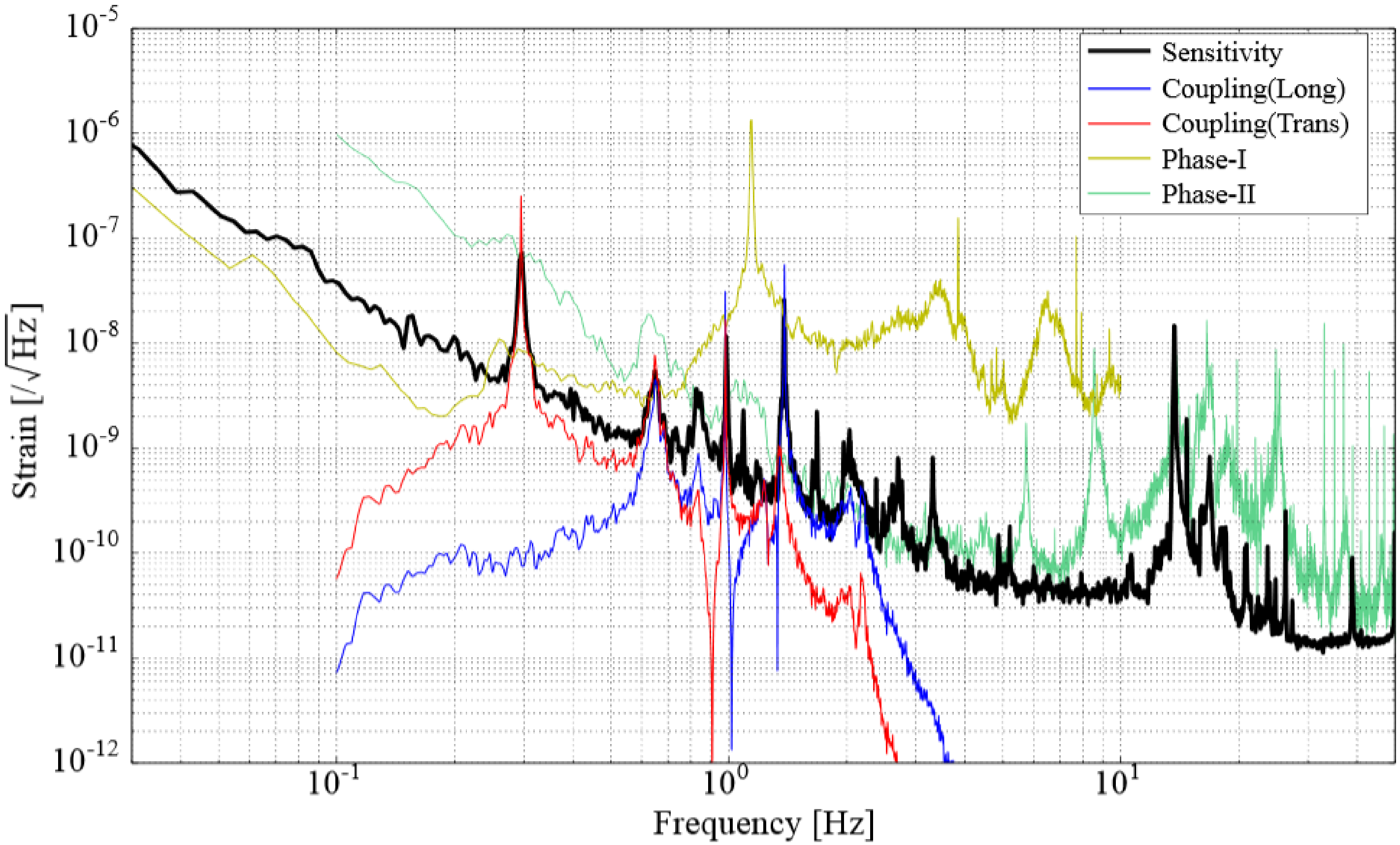
$$\sqrt{S(f)} = 8.9 \times 10^{-19} \sqrt{h_0^2 \Omega_0} \left(\frac{\text{Hz}}{f}\right)^{3/2} / \sqrt{\text{Hz}}$$



Y. Kuwahara +, [PRD 94, 042003 (2016)]

uHz GWB with Rotating TOBA

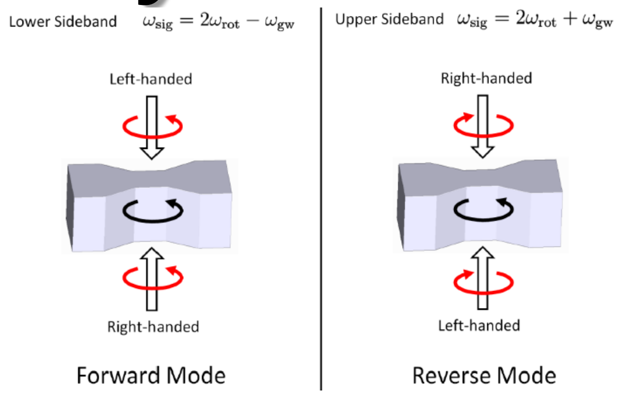
- If rotate TOBA by 0.1 Hz, with current TOBA sensitivity, we can search for 1 uHz GWB at $h_0^2\Omega_0 \sim 1 \times 10^4$ level
- It will be the first demonstration on Earth

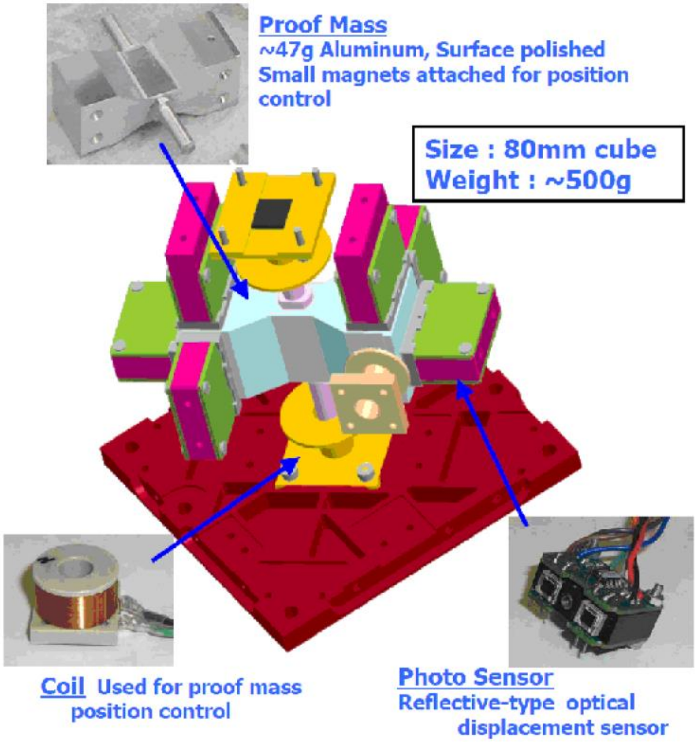


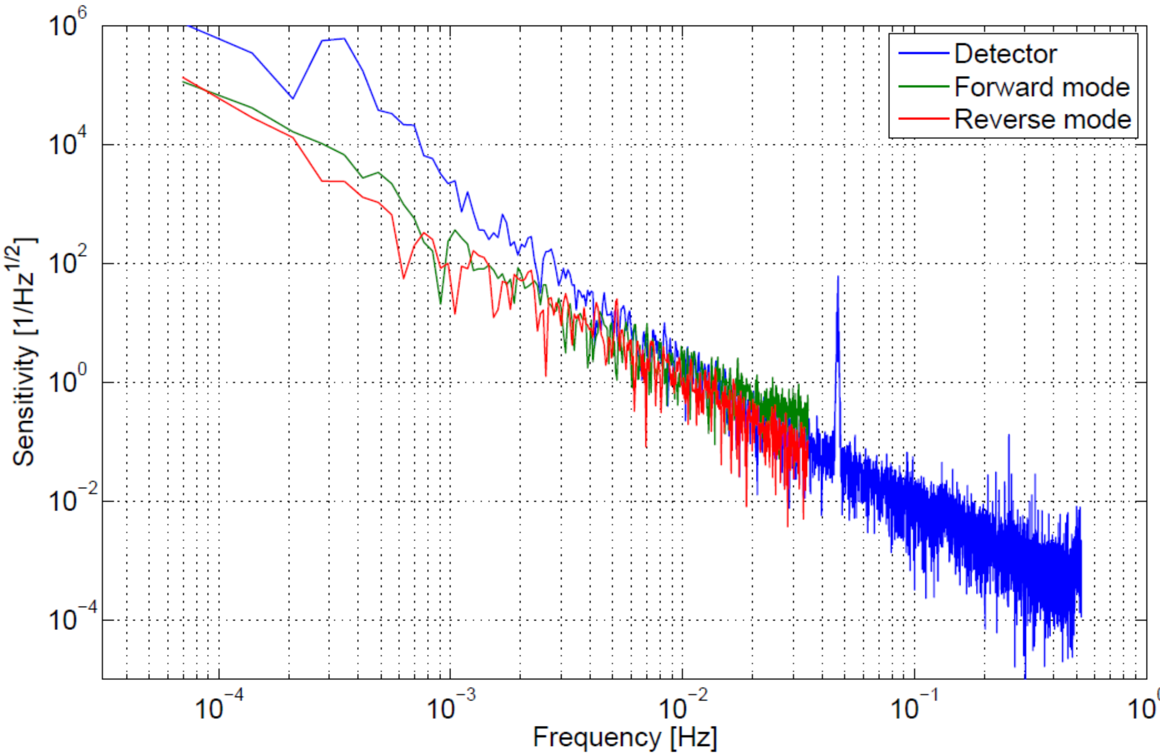
T. Shimoda, Master Thesis (2017)

SWIMμv Sensitivity

- Rotation freq. 46.5mHz, $h_0^2\Omega_0 \lesssim 10^{30}$ at 18 mHz
- 2 bars needed to distinguish two polarizations

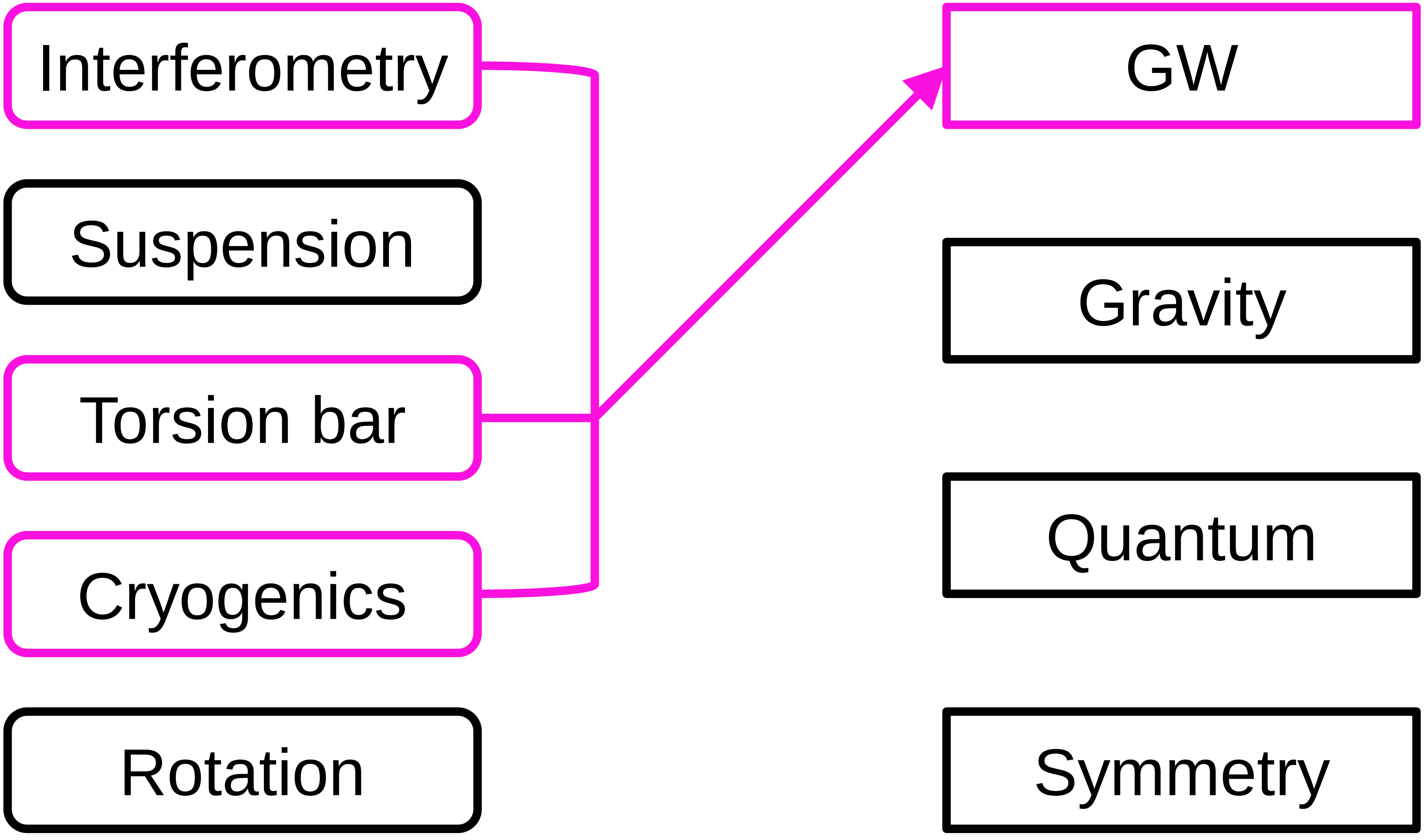






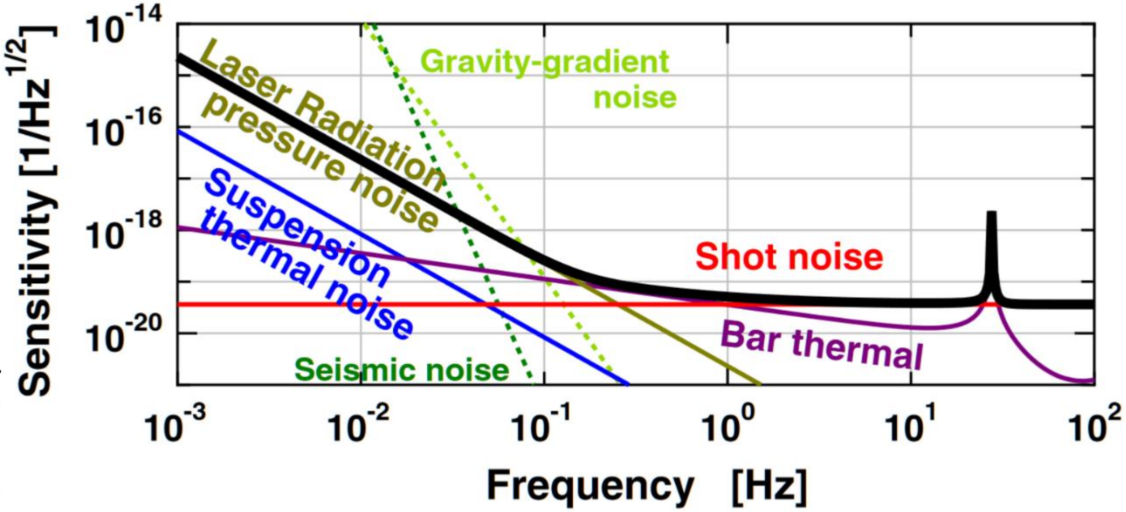
W. Kokuyama, Doctoral Thesis (2012)

Cryogenic TOBA

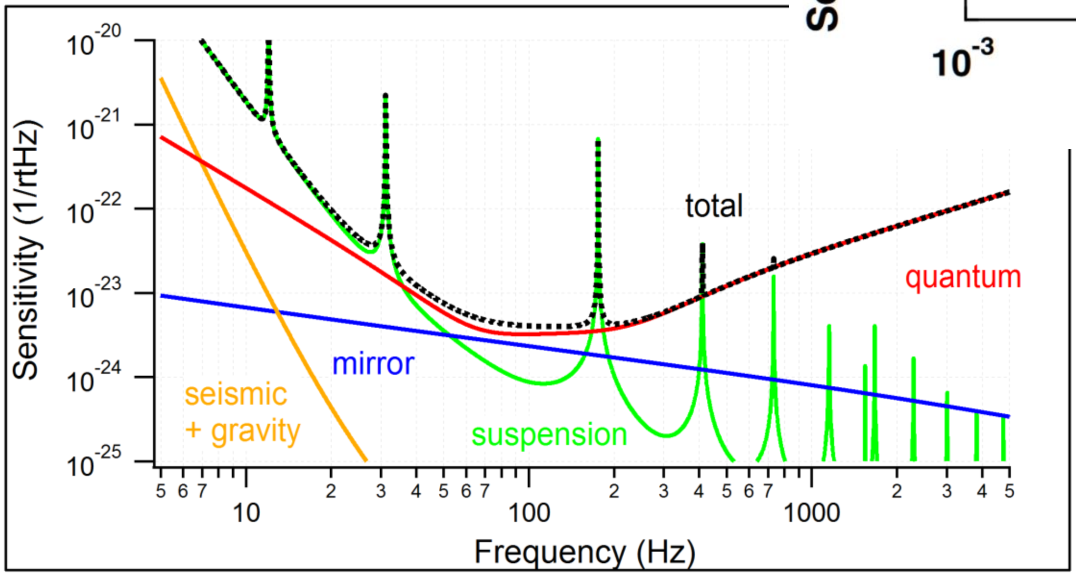


Suspension Thermal is Killing Us

- serious study on cryogenic suspension needed not only for TOBA, but also for KAGRA (and 3G detectors)



M. Ando +, [PRL 105, 161101 (2010)](#)
4 K, φ = 1e7



http://gwwiki.icrr.u-tokyo.ac.jp/JGWwiki/KAGRA
23 K, φ = 2e7

Suspension Thermal Noise

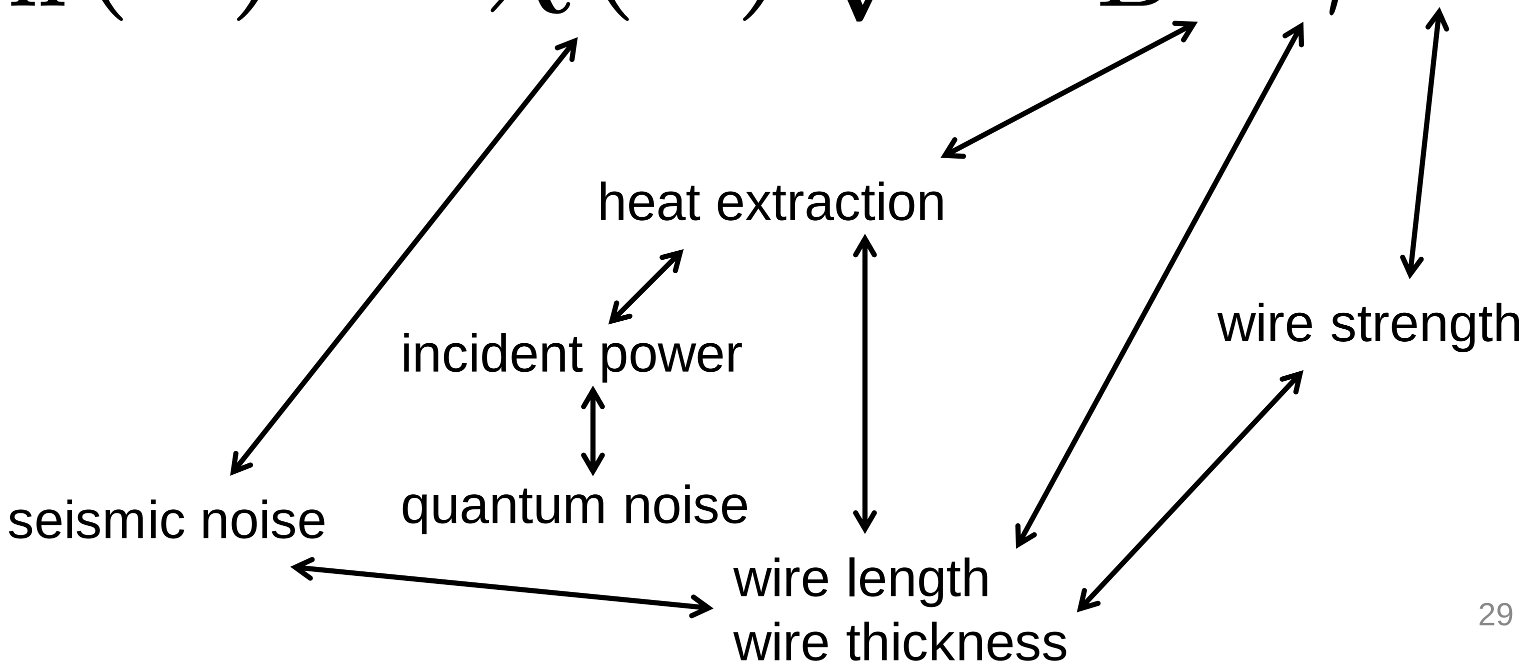
- Many things are entangled
- Needs clever optimization

$$S_{\mathrm{th}}(\omega) = \chi(\omega)\sqrt{4k_{\mathrm{B}}T\gamma m}$$

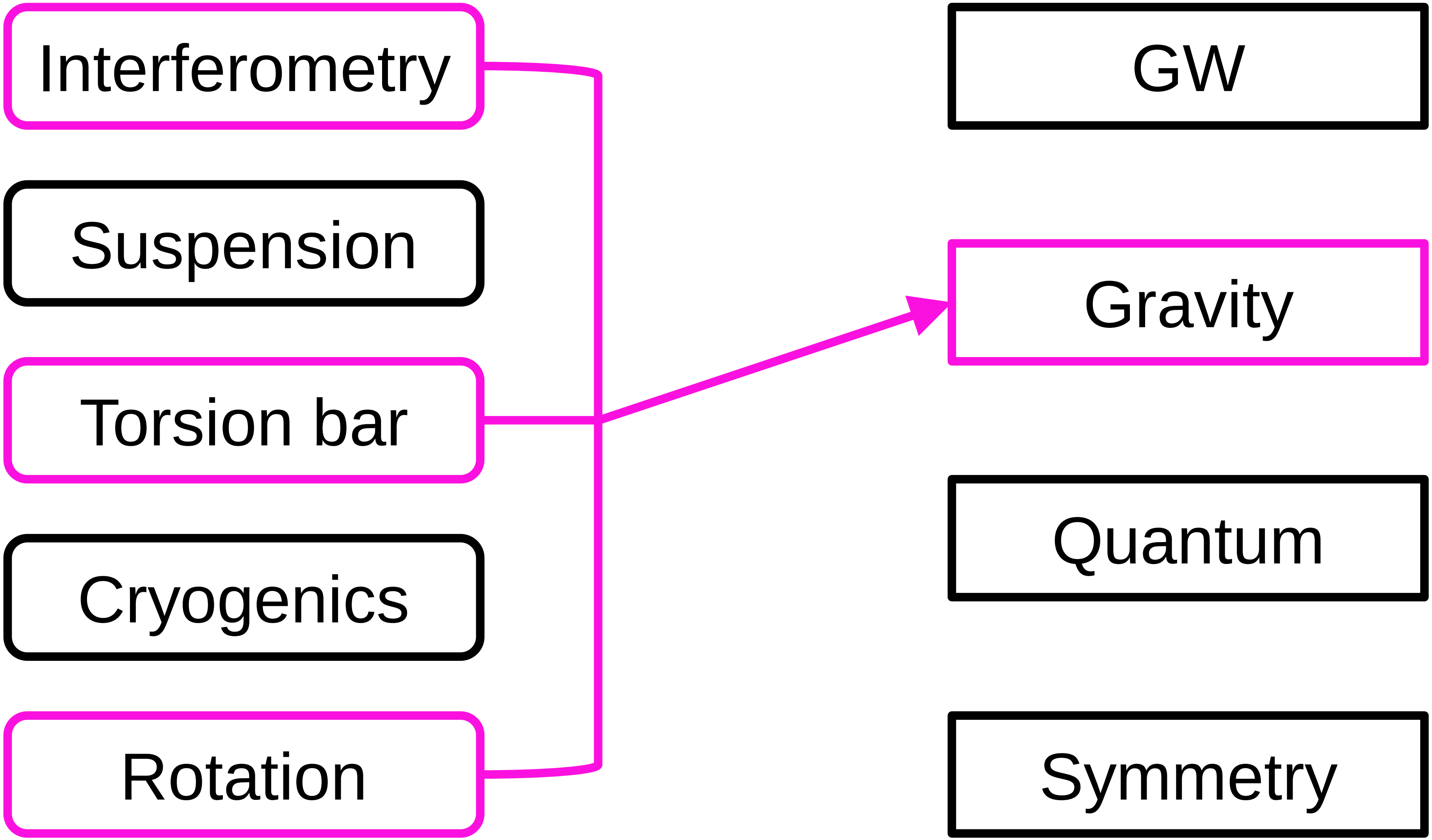
Suspension Thermal Noise

- Many things are entangled
- Needs clever optimization

$$S_{\mathrm{th}}(\omega) = \chi(\omega)\sqrt{4k_{\mathrm{B}}T\gamma m}$$

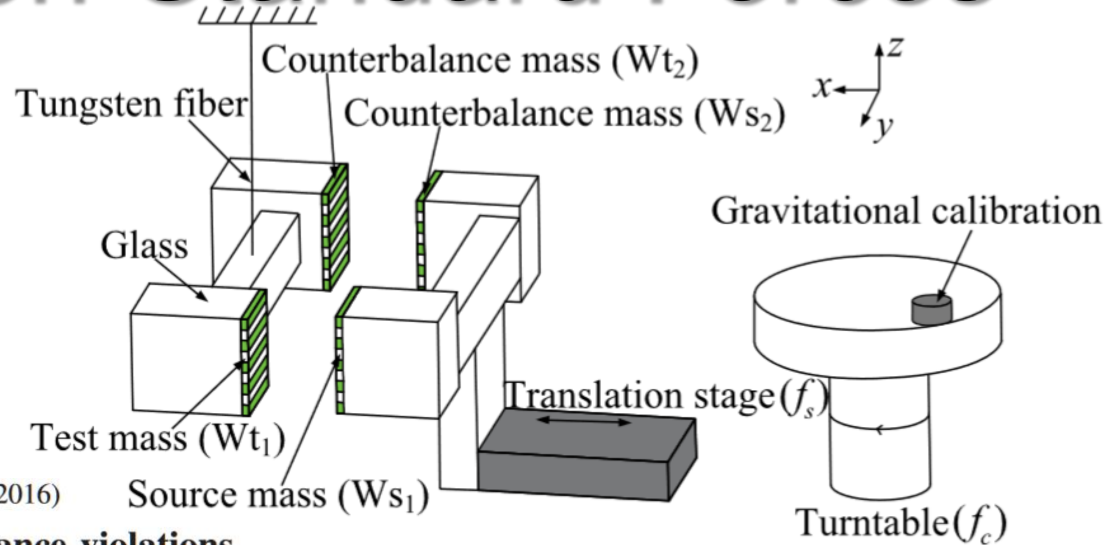


Gravitational Inverse Square Law



Search for Non-Standard Forces

- Sounds fun
- Axion, dark matter, dark energy……
- Also related to Lorentz violation



PHYSICAL REVIEW D **94,** 104061 (2016)

Enhanced sensitivity to Lorentz invariance violations in short-range gravity experiments

Cheng-Gang Shao, Ya-Fen Chen, Yu-Jie Tan, Jun Luo, and Shan-Qing Yang[*]
Key Laboratory of Fundamental Physical Quantities Measurement of Ministry of Education, School of Physics, Huazhong University of Science and Technology, Wuhan 430074, People's Republic of China

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School of Physics, University of Western Australia, Crawley, Western Australia 6009, Australia
(Received 18 August 2016; published 28 November 2016)

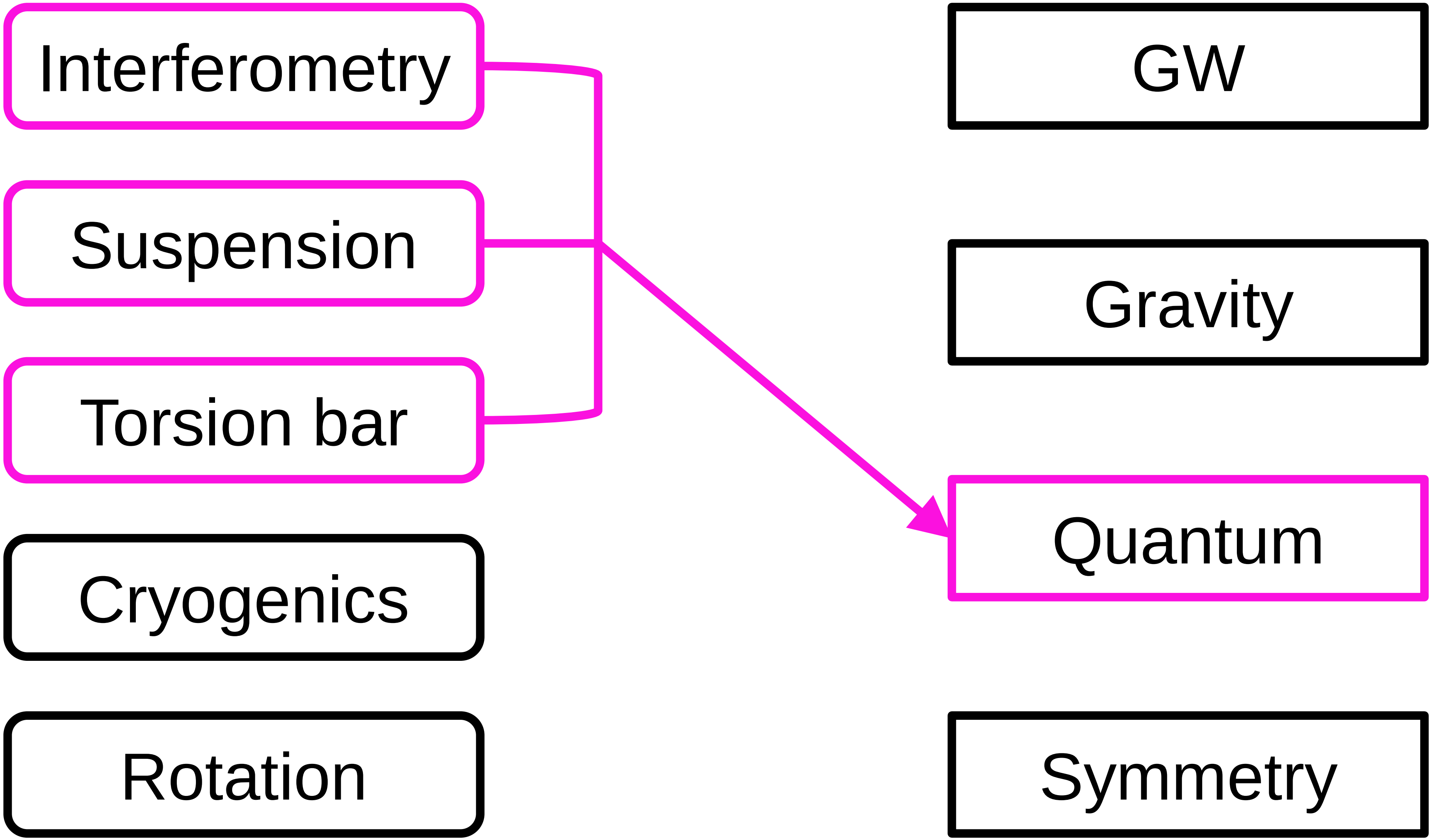
Recently, first limits on putative Lorentz invariance violation coefficients in the pure gravity sector were determined by the reanalysis of short-range gravity experiments. Such experiments search for new physics at sidereal frequencies. They are not, however, designed to optimize the signal strength of a Lorentz invariance violation force; in fact the Lorentz violating signal is suppressed in the planar test mass geometry employed in those experiments. We describe a short-range torsion pendulum experiment with enhanced sensitivity to possible Lorentz violating signals. A periodic, striped test mass geometry is used to augment the signal. Careful arrangement of the phases of the striped patterns on opposite ends of the pendulum further enhances the signal while simultaneously suppressing the Newtonian background.

DOI: 10.1103/PhysRevD.94.104061

PRD 94, 104061 (2016)

PROPOSAL

Macroscopic Quantum Mechanics



Hurdles for Optical Levitation

- Mirror fabrication
  - needs serious discussion with mirror people
- Torsion pendulum experiment
  - how to see yaw resonant frequency change?
  - yaw frequency never matches expectation
- SQL
  - tough to reach SQL
  - frequency stabilization
  - rotational degrees of freedom?

- Nanoparticle levitation
  also sounds fun and relevant to
  technology we have
  (Titech Aikawa Lab)

Nanoparticle 1

PRL **117,** 101101 (2016) PHYSICAL REVIEW LETTERS week ending 2 SEPTEMBER 2016

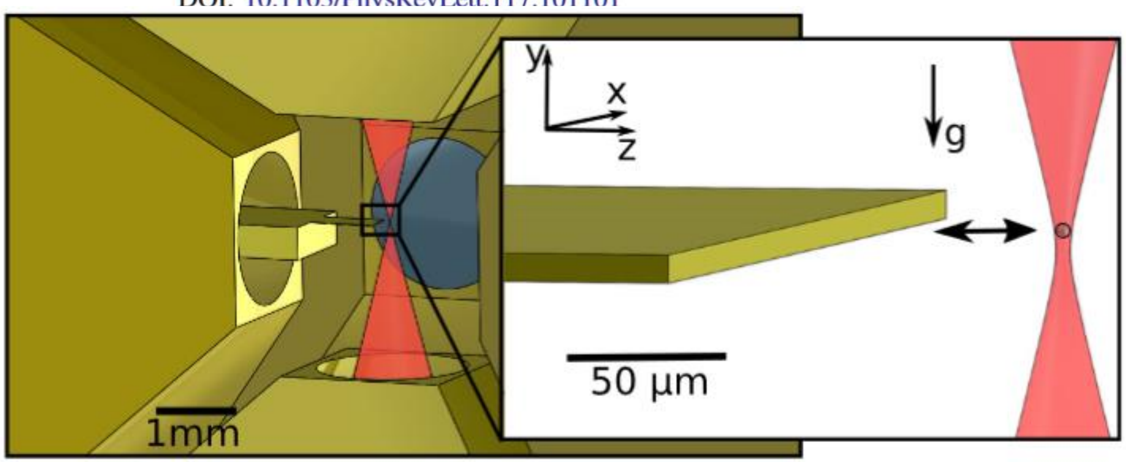
PRL 117, 101101 (2016)

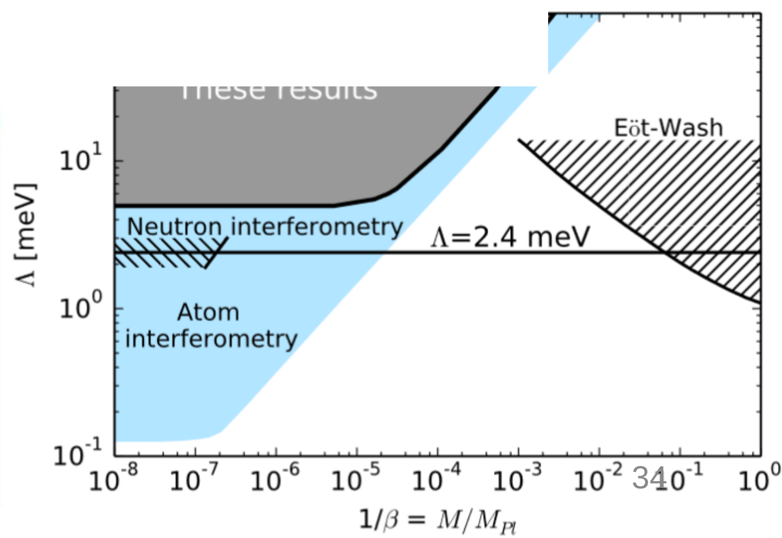
Search for Screened Interactions Associated with Dark Energy below the 100 μm Length Scale

Alexander D. Rider,[1,*] David C. Moore,[1] Charles P. Blakemore,[1] Maxime Louis,[2] Marie Lu,[1] and Giorgio Gratta[1]
[1]*Department of Physics, Stanford University, Stanford, California 94305, USA*
[2]*Department of Physics, École Polytechnique, 91128 Palaiseau, France*
(Received 21 April 2016; revised manuscript received 31 May 2016; published 29 August 2016)

We present the results of a search for unknown interactions that couple to mass between an optically levitated microsphere and a gold-coated silicon cantilever. The scale and geometry of the apparatus enable a search for new forces that appear at distances below 100 μm and which would have evaded previous searches due to screening mechanisms. The data are consistent with electrostatic backgrounds and place upper limits on the strength of new interactions at < 0.1 fN in the geometry tested. For the specific example of a chameleon interaction with an inverse power law potential, these results exclude matter couplings $\beta > 5.6 \times 10^4$ in the region of parameter space where the self-coupling $\Lambda \gtrsim 5$ meV and the microspheres are not fully screened.

DOI: 10.1103/PhysRevLett.117.101101





Nanoparticle 2

PHYSICAL REVIEW D **95,** 044014 (2017)

Nanogravity gradiometer based on a sharp optical nonlinearity in a levitated particle optomechanical system

[PRD 95, 044014 (2017)]

PROPOSAL

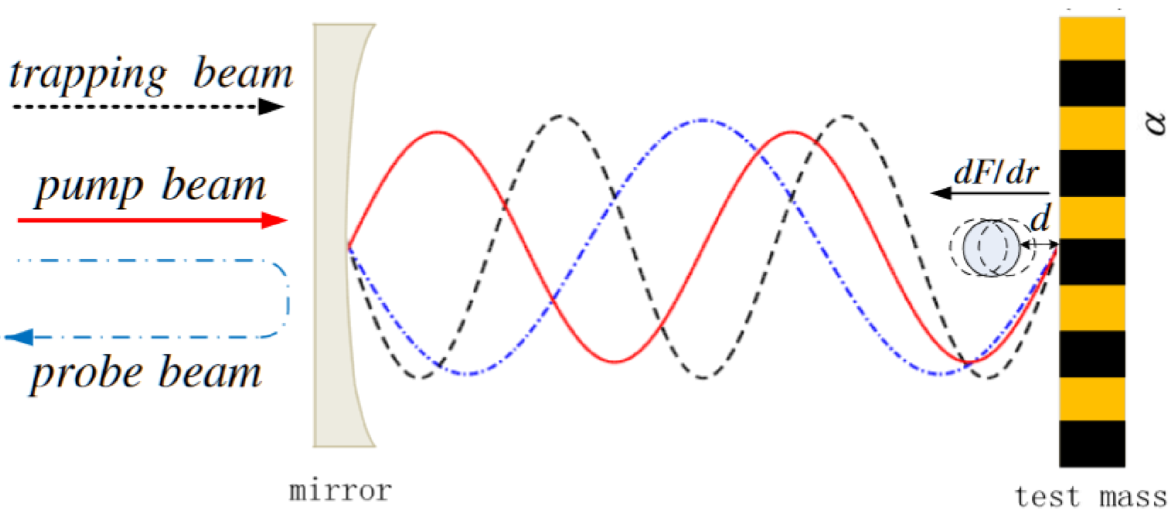
Jian Liu and Ka-Di Zhu*

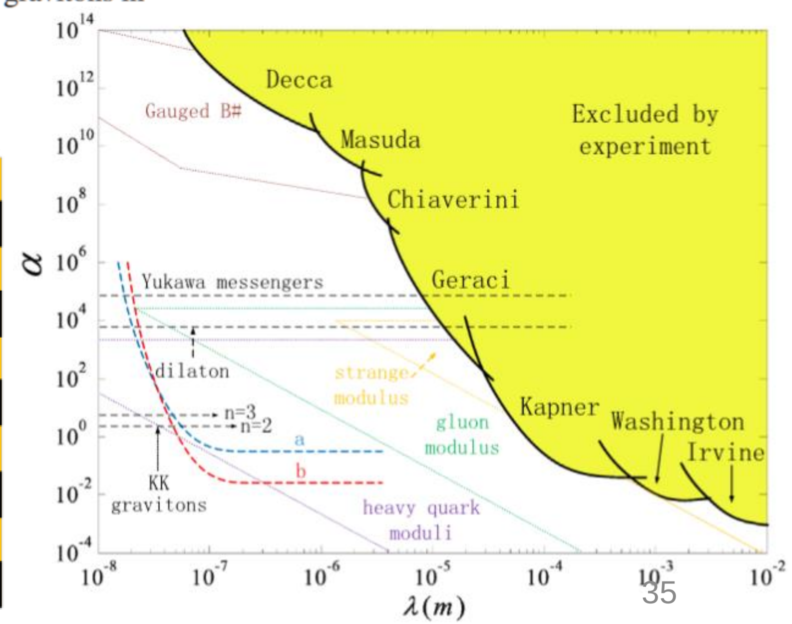
Key Laboratory of Artificial Structures and Quantum Control (Ministry of Education), Department of Physics and Astronomy, Shanghai Jiao Tong University, 800 DongChuan Road, Shanghai 200240, China

(Received 19 October 2016; published 13 February 2017)

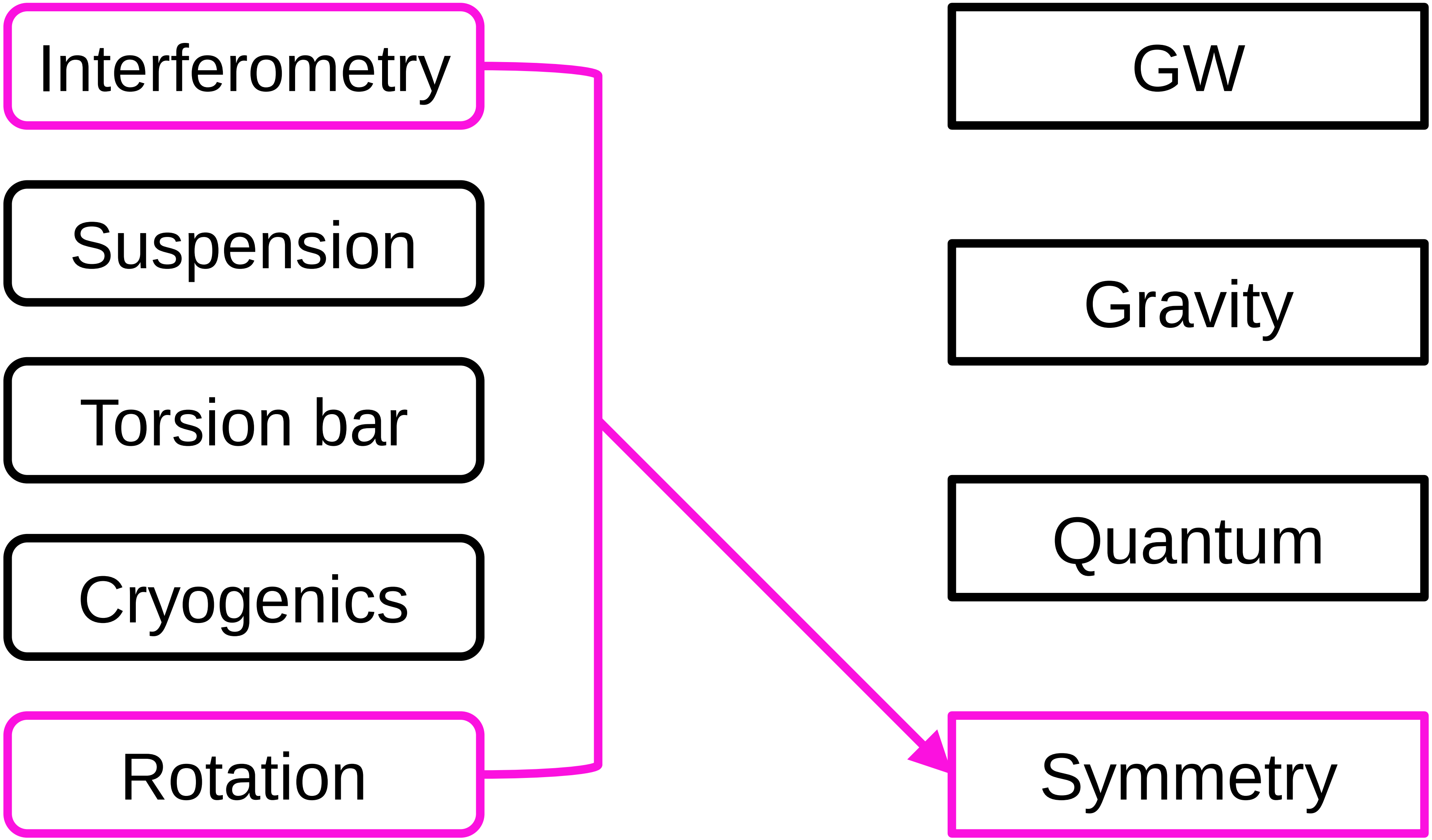
In the present paper, we provide a scheme to probe the gradient of gravity at the nanoscale in a levitated nanomechanical resonator coupled to a cavity via two-field optical control. The enhanced sharp peak on the probe spectrum will suffer a distinct shift with the nonuniform force being taken into consideration. The nonlinear optics with very narrow bandwidth (10^{-8} Hz) resulting from the extremely high-quality factor will lead to a superresolution of 10^{-20} N/m for the measurement of gravity gradient. The improved sensitivity may offer new opportunities for detecting Yukawa moduli forces and Kaluza-Klein gravitons in extra dimensions.

DOI: 10.1103/PhysRevD.95.044014



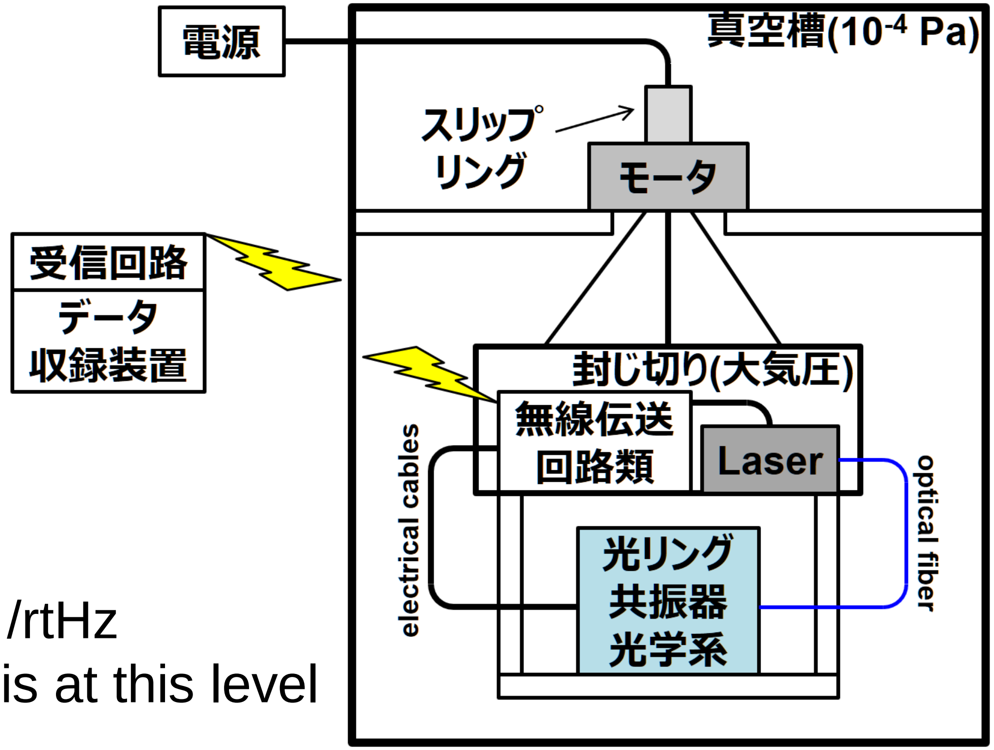


Lorentz Invariance Test



Things To Do

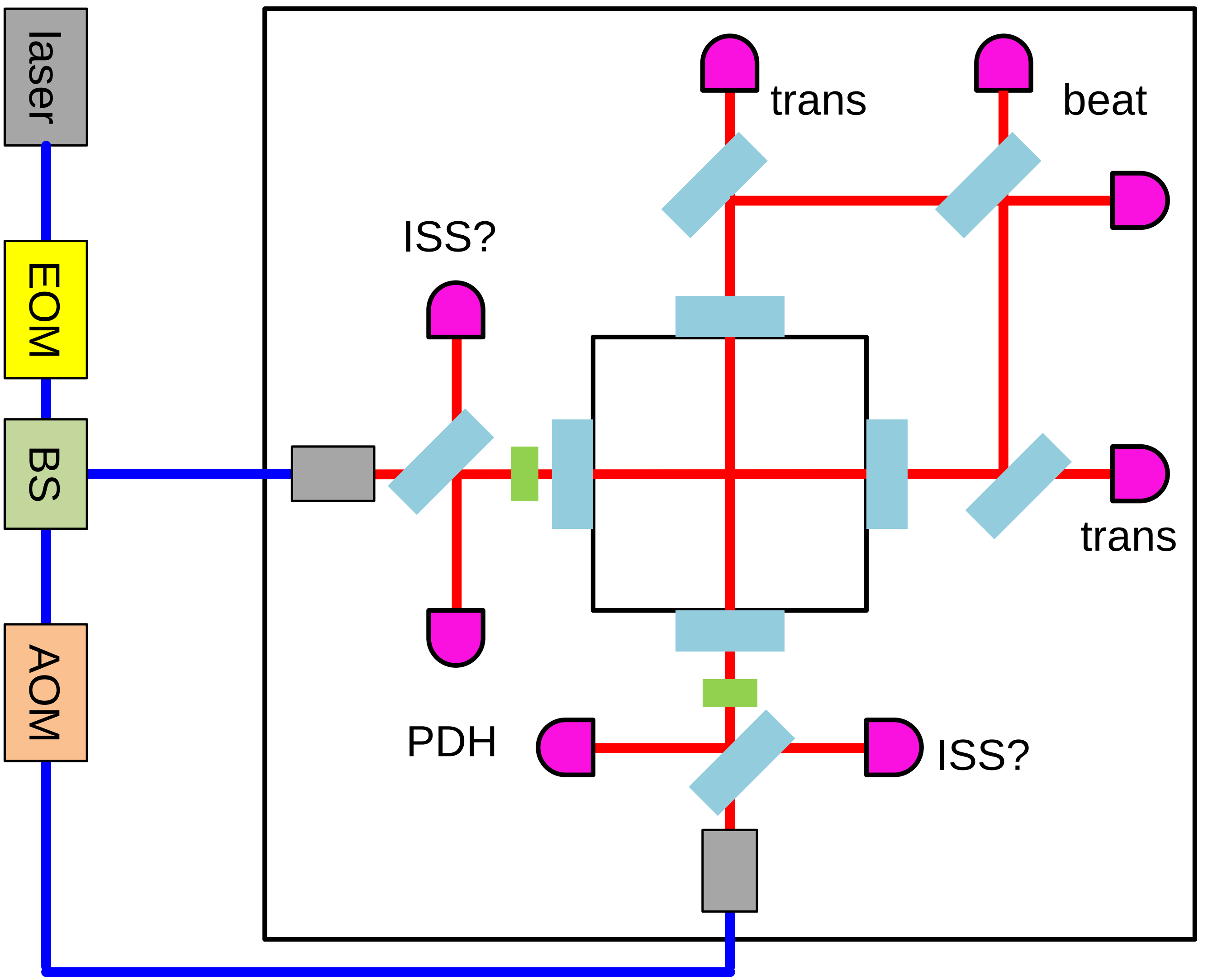
- Monolithic optics
  - important for space mission
  - cavity with monolithic collimator not done (to my knowledge)
  - but may not be so effective
  - still many things to be done with semi-monolithic optics
- Magnetic shield
  - TN said it should be easy
- Suspend the setup
  - for vibration isolation
  - for passive tilt control



- Even-parity experiment
  - to go better than 10^{-19} in a year, fractional freq. noise should be better than ~ 10^{-16} /rtHz
  - thermal noise at room temp. is at this level for ~10cm fused silica cavity
  - even-parity is more competitive but also draws more attention

Example Even-Parity Setup

- Thermal noise reduction needed to go beyond 10^{-20}



Summary

- Science is tough
- Think carefully but don't be too picky