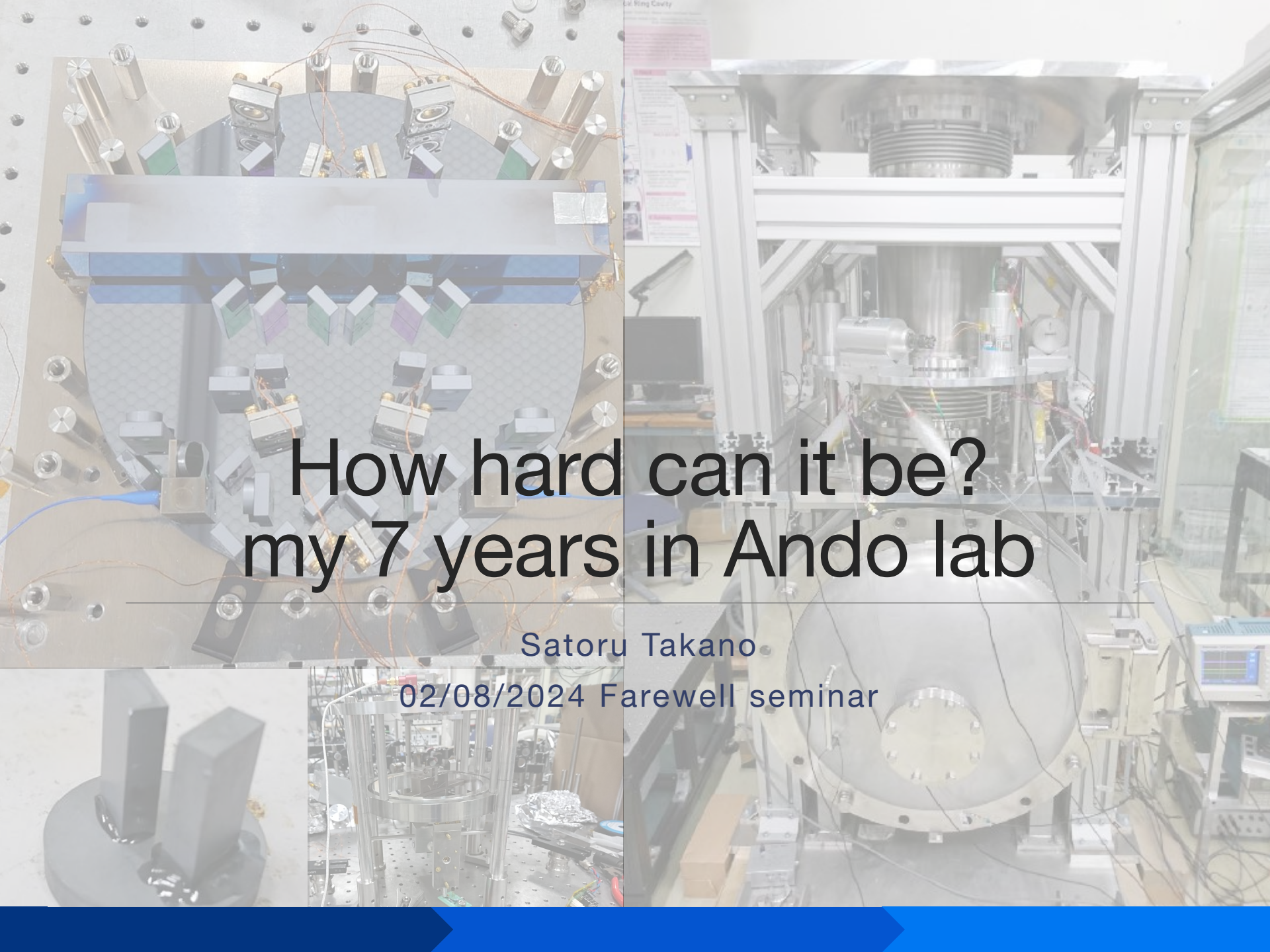


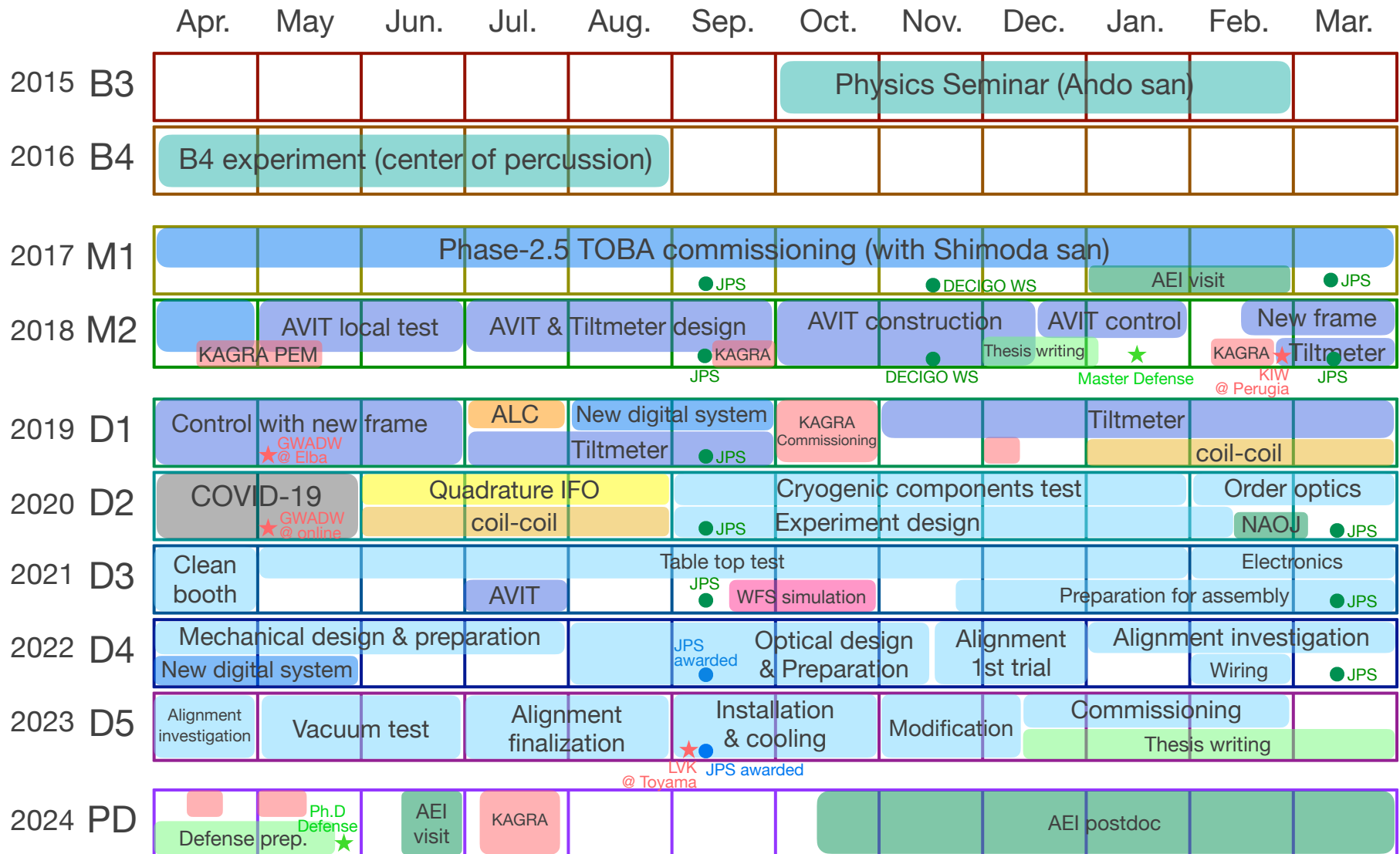


How hard can it be?
my 7 years in Ando lab

Satoru Takano

02/08/2024 Farewell seminar

History of my research



Contents

- Looking back on what I did
- Random thoughts
- What I will do in future

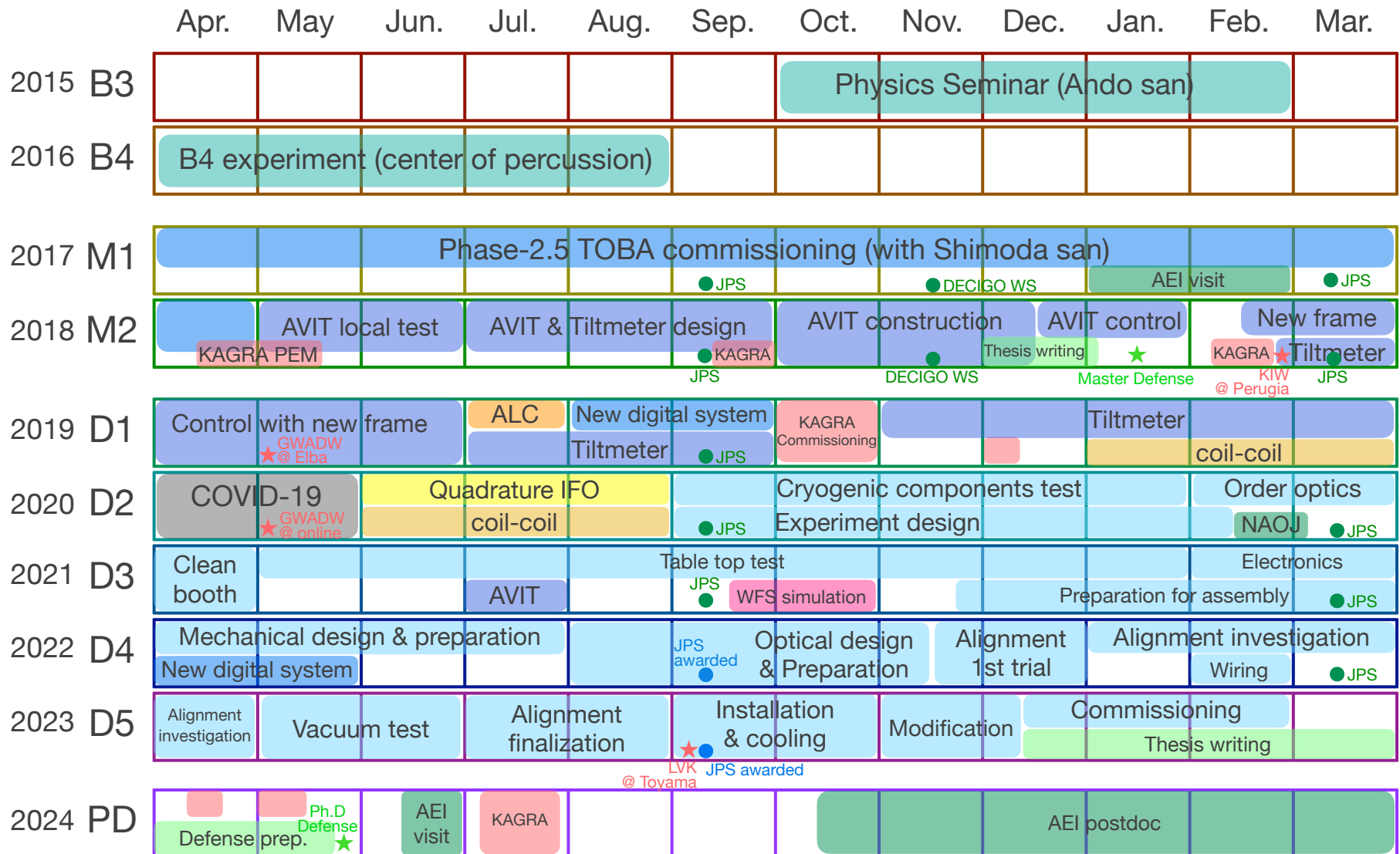


Contents

- **Looking back on what I did**
- Random thoughts
- What I will do in future

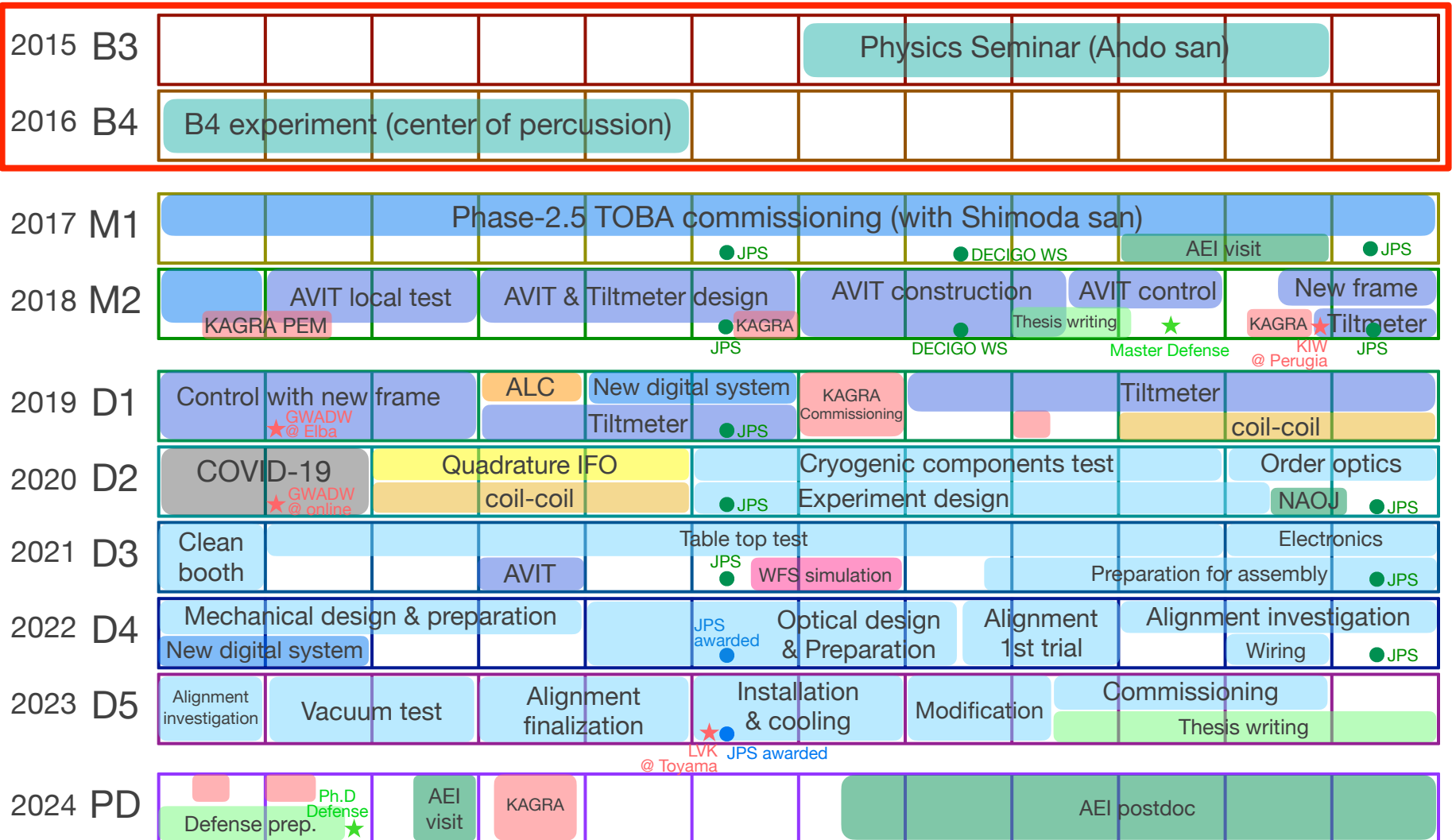


History of my research



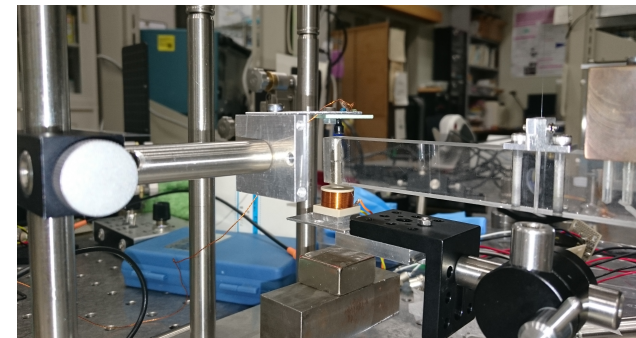
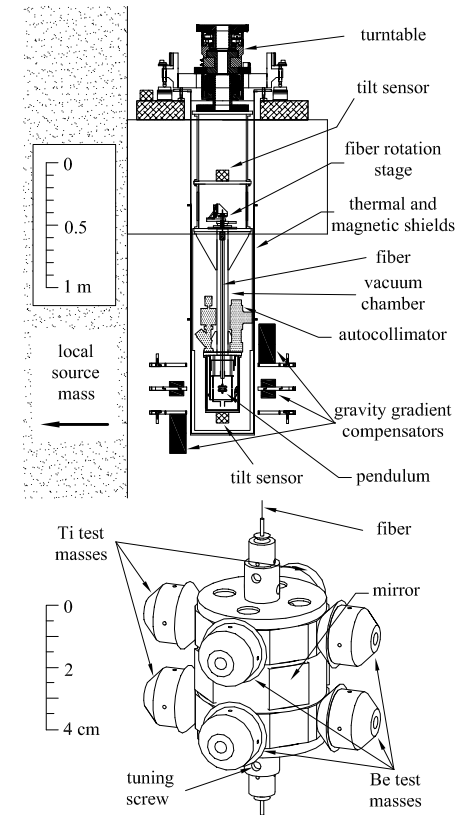
History of my research

Apr. May Jun. Jul. Aug. Sep. Oct. Nov. Dec. Jan. Feb. Mar.

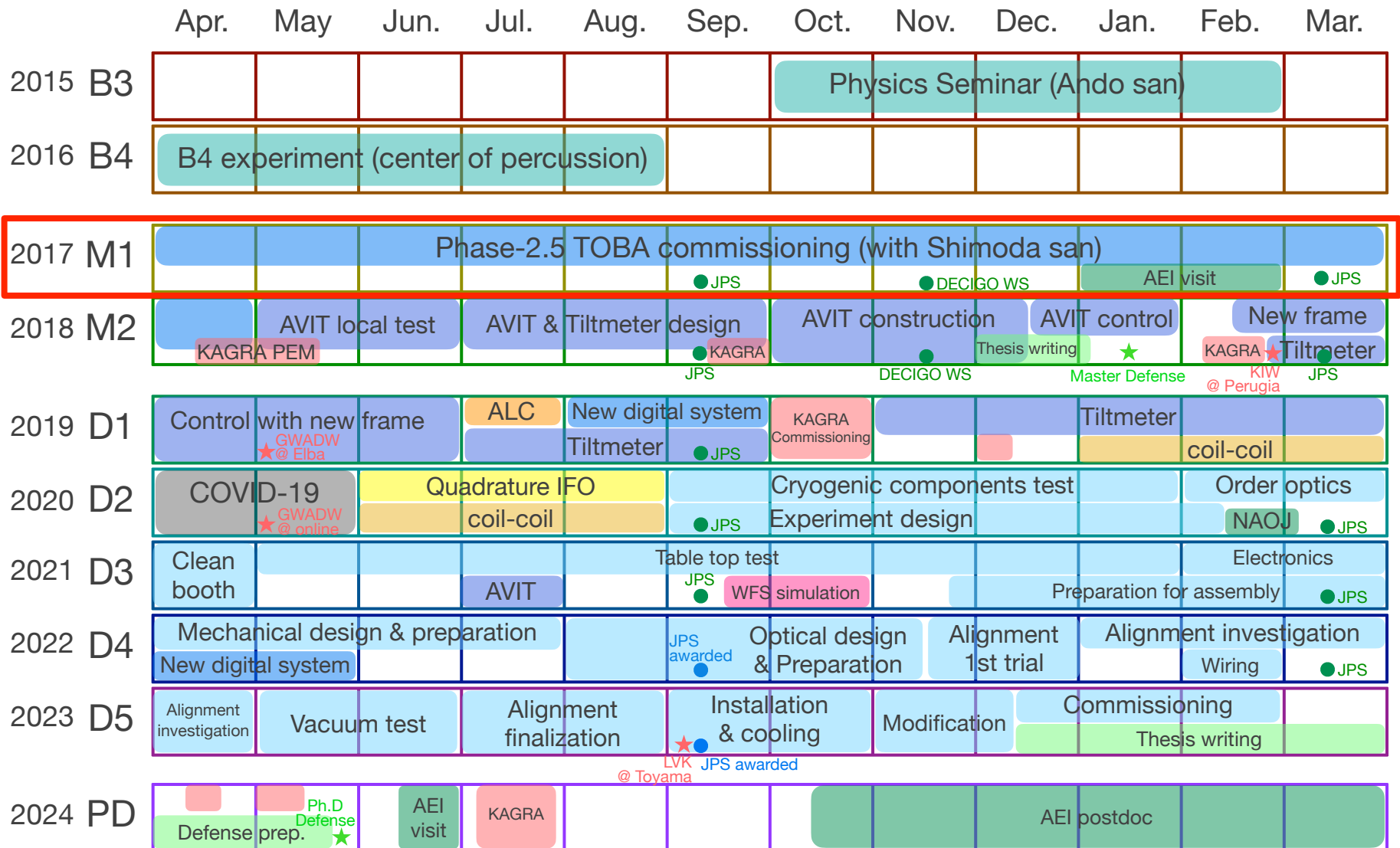


Undergrad

- B3: Physics seminar (Mentor: Ando san)
 - Read papers related to GW physics and precise measurement
 - What I read: torsion pendulum experiment in UW (2008)
 - At the end of the semester I did a presentation about GW physics (Brans-Dicke theory, if my memory is correct...)
- B4: Experiment at Ando lab in S semester
 - Topics: Displacement noise cancellation by center of percussion effect
 - Hard to construct the setup at that time
 - ▶ I did it alone
 - ▶ Magnetic levitation, control, ...



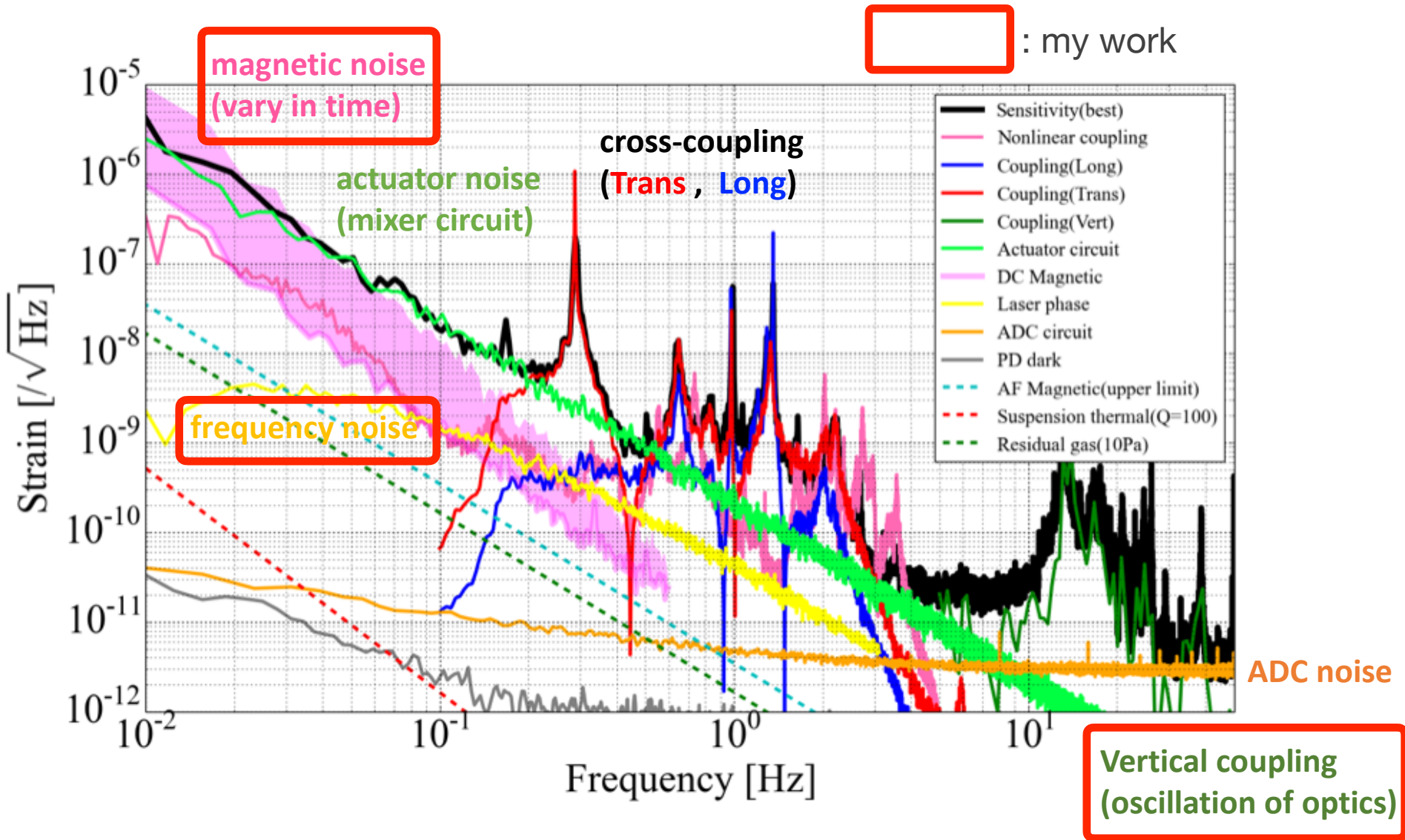
History of my research



Commissioning of TOBA

- Noise hunting of Phase-2.5 TOBA (Shimoda san's setup)
 - Learned so many thing from Shimoda san about GW detectors
 - Suspension, torsion pendulum, cross coupling
 - Interferometer (Michelson)
 - Power spectral density, transfer function
 - Digital system (LIGO CDS)
 - ▶ Unfortunately almost all of them were above my understanding at that time...
 - Found that **noise hunting is fun**
 - ▶ Until unknown noise appears and limits the sensitivity...
 - ▶ We should have spent more time to pursuit better sensitivity
- Considering Phase-III TOBA
 - Cryogenic, interferometer, vibration isolation, ...
 - Have to choose my research topic for master thesis

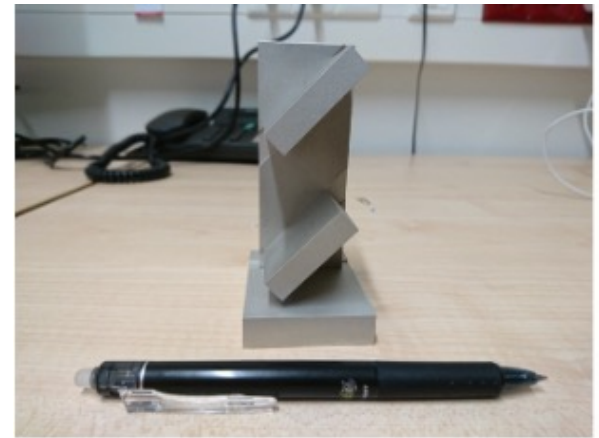
Final sensitivity of Phase-2.5



Visit of AEI

I visited AEI for two month, from January 2018 to February 2018

- Joined to Michèle Here's group (Quantum control)
 - Measurement of characteristics of a new laser (output power, frequency stability, ...)
 - Power stabilization



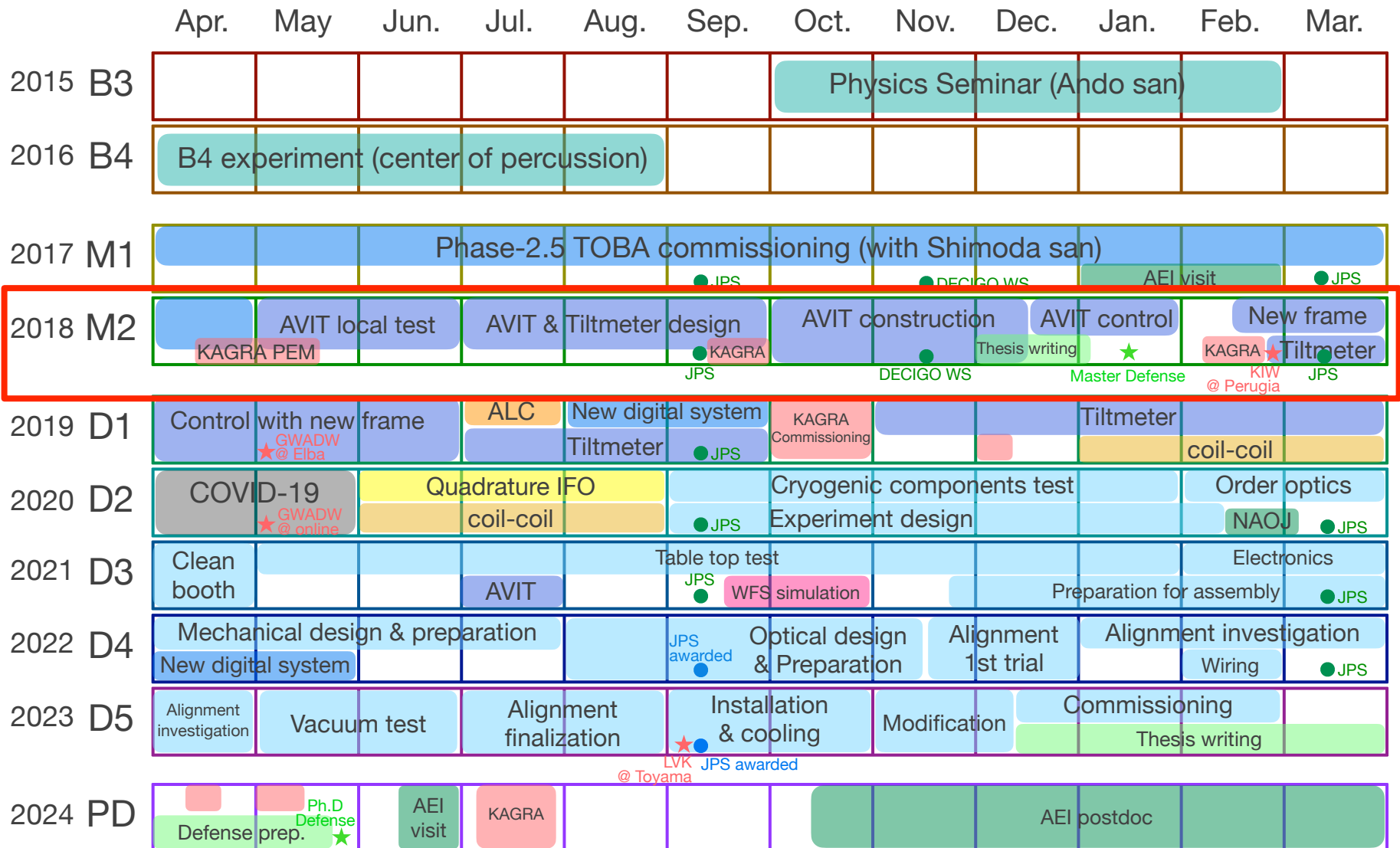
Visit of AEI

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- Joined to Michèle Here's group (Quantum control)
 - Measurement of characteristics of a new laser (output power, frequency stability, ...)
 - Power stabilization
- That was my first time in Europe and long-term stay abroad
 - Stuck at the passport control ~ 1 hour due to my poor English
 - Luckily there was a friend in Berlin at that time
 - I got used to staying abroad



History of my research



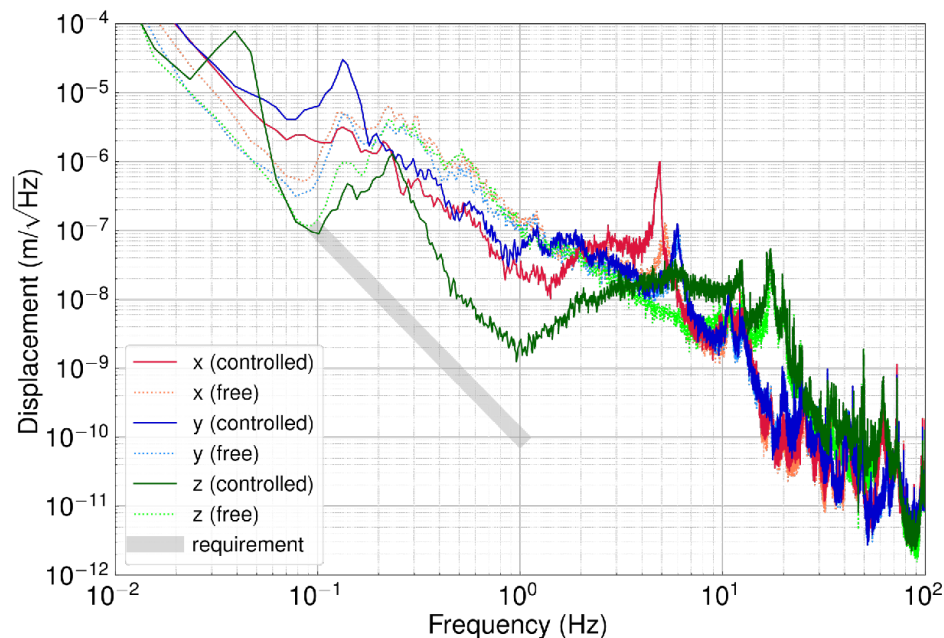
Topics theme for master thesis

- Topic candidates: necessary technique for Phase-III TOBA
 - WFS → Miyazaki kun, Oshima san
 - Cryogenic → Shimoda san
 - AVIT
 - (Monolithic → my Ph.D thesis)
- I don't remember why I chose AVIT any more...
 - Actually I was interested in WFS, but I avoided it because new WFS is Shimoda san's idea and he already started a experiment
 - Perhaps no strong reason for AVIT
- I started working on AVIT from May
 - **8 months** were left for the submission
 - Too late to start a brand new experiment?
 - ▶ Maybe yes if you are a master student and ask no help

AVIT Performance in master thesis

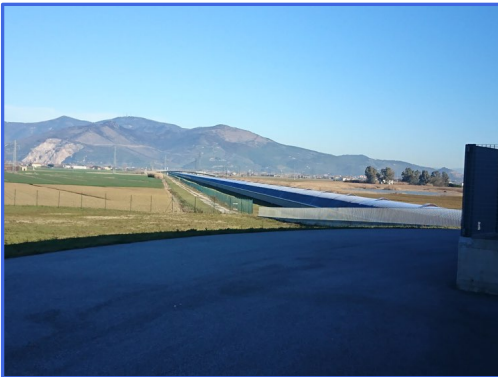
- Terrible Frame
 - ▶ Apparently weak structure
- Original chamber frame
 - Basically same as that of Phase-II TOBA

Took this data 2 days before submission

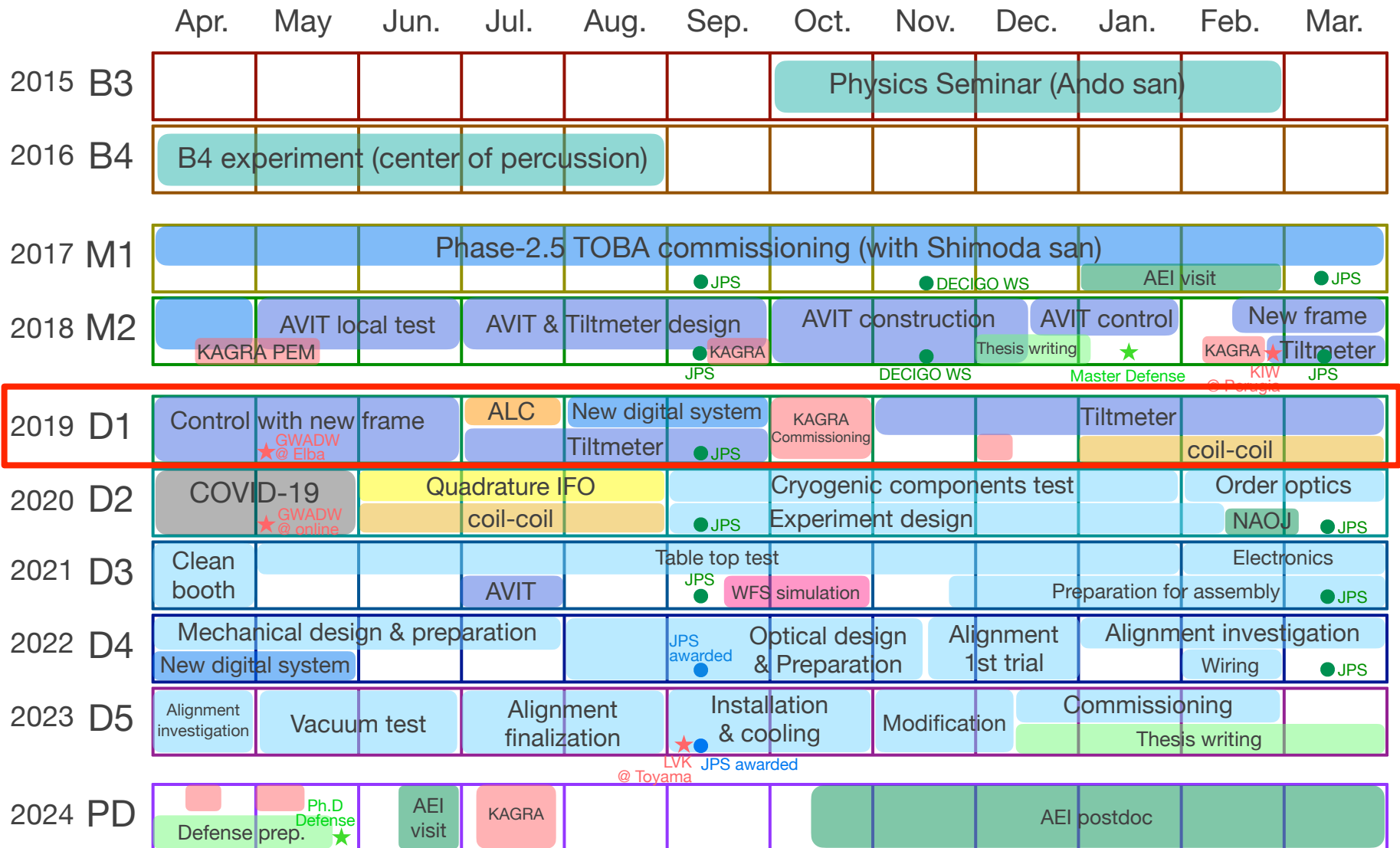


KIW @ Perugia, Italy

Kind of a graduation trip with my friends

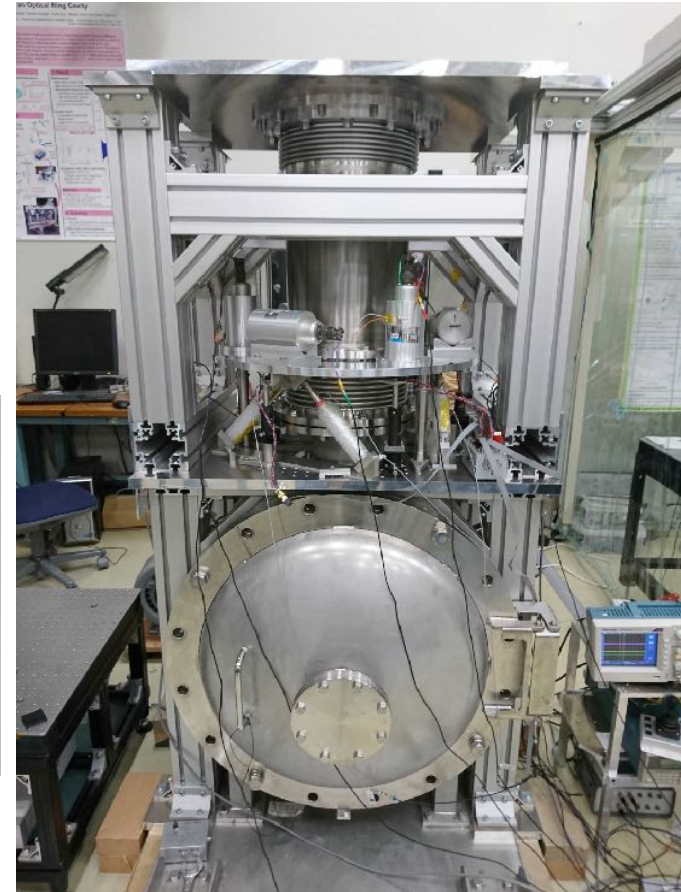
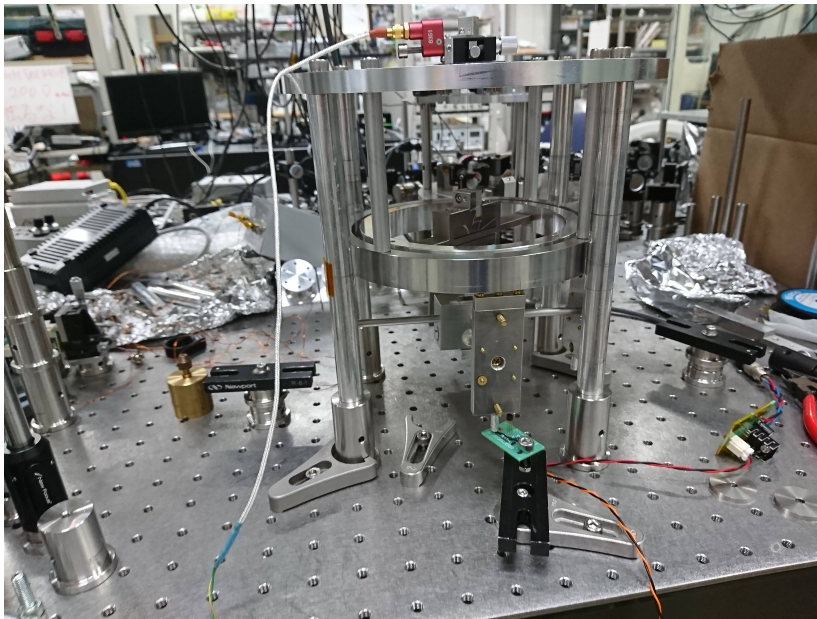


History of my research



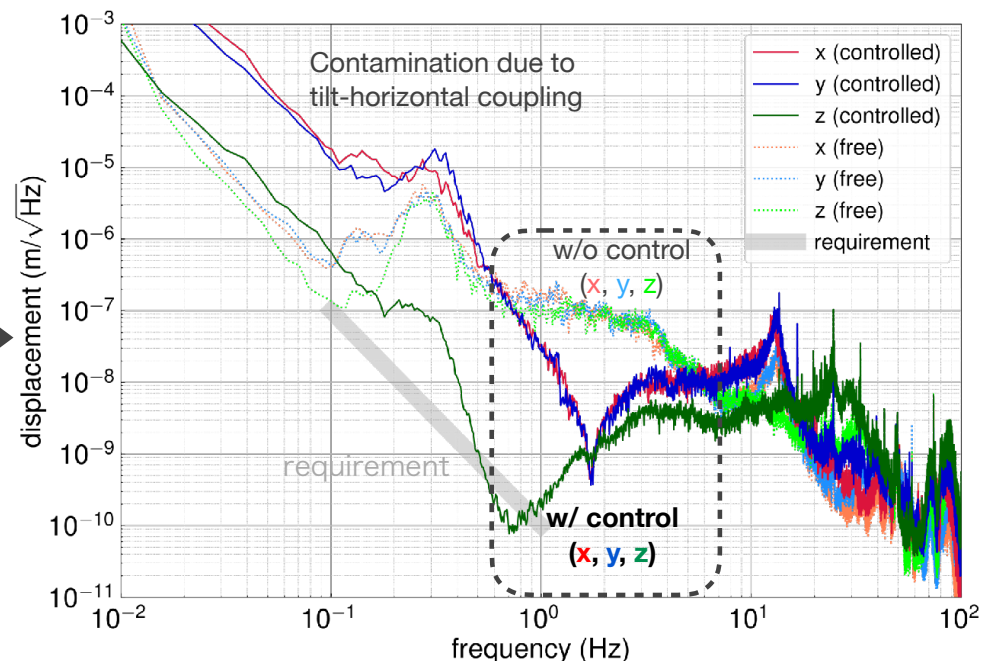
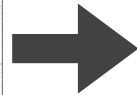
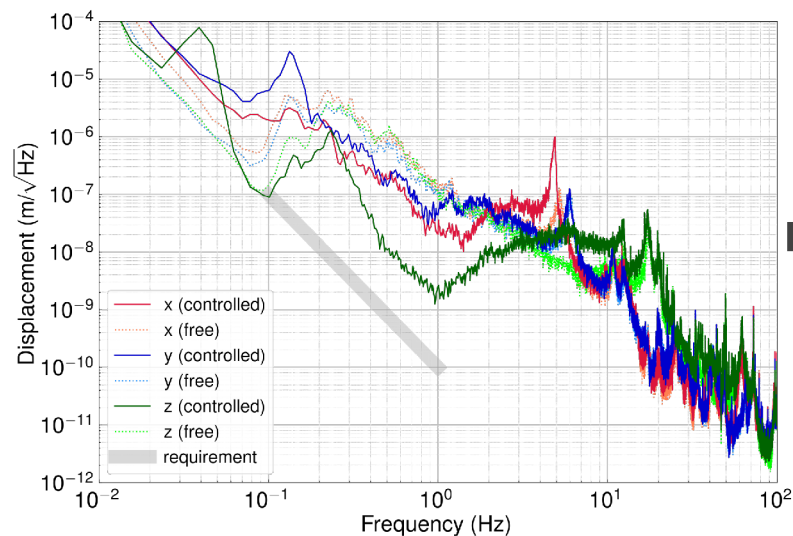
Activities in D1

- Activities in D1
 - Better control of AVIT
 - Development of Tiltmeter
 - KAGRA commissioning
- None of them are related to the thesis work...



New frame for AVIT

- Reviewed the setup
 - Replaced the original structure with aluminum frames
 - Removed casters
 - Changed the filter design (following GW detectors)
 - ▶ Finally succeeded in locking 3 axis (x, y, z) at the same time
 - ▶ Best performance so far



GWADW 2019 @ Elba

Awesome meeting except my talk was in the last day...



Development of Cryogenic Torsion-Bar Gravitational Wave Detector

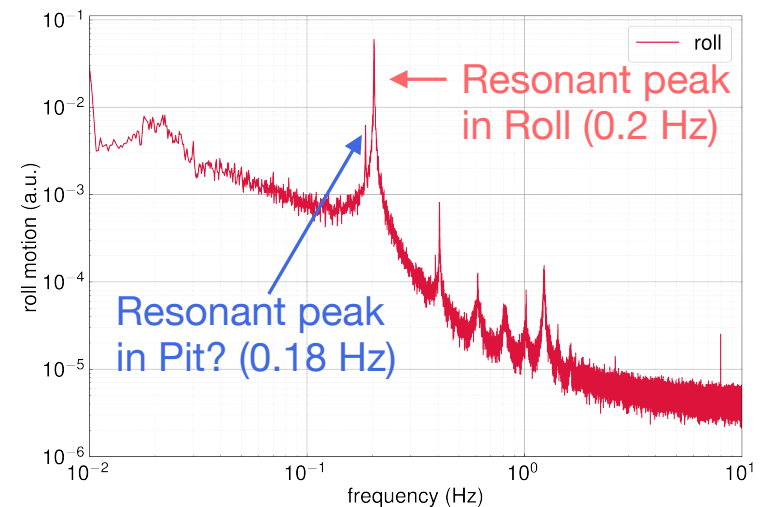
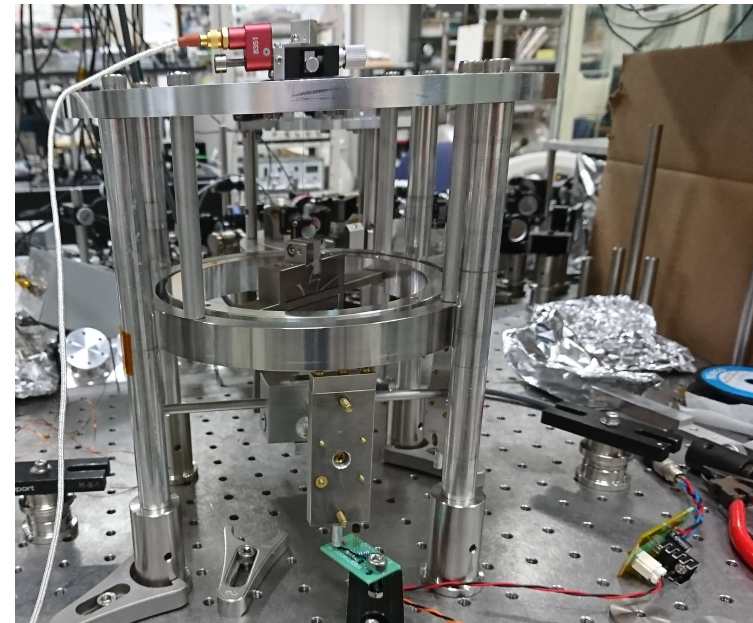
Satoru Takano, Tomohumi Shimoda, Ching Pin Ooi, Yuki Miyazaki,
Yuta Michimura, Masaki Ando
The Univ. of Tokyo
24/05/19 GWADW2019 @ Elba



Development of tiltmeter

- Began to focus on tiltmeter
- Resonant frequency tuning in tilt
 - Target: < 30 mHz
 - ▶ Crazy requirement!
 - Hard to tune it
 - ▶ Not reproducible, changed in time (due to temperature?)
 - ▶ Hard to tune it by hand (adding counter weights)
 - ▶ In air measurement
 - A lot of design failures
- Gradually reluctant to do it...
 - ▶ Ran away to KAGRA

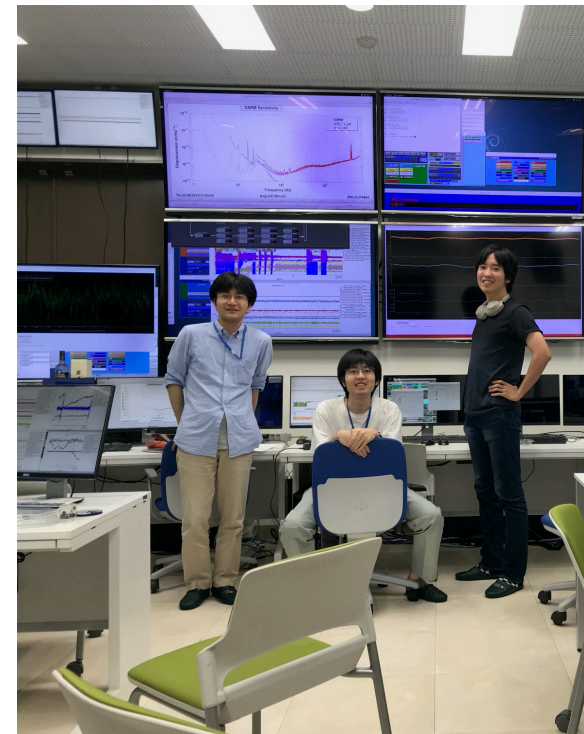
I'm very sorry for giving it up...



KAGRA commissioning

Stayed for a month (in October)

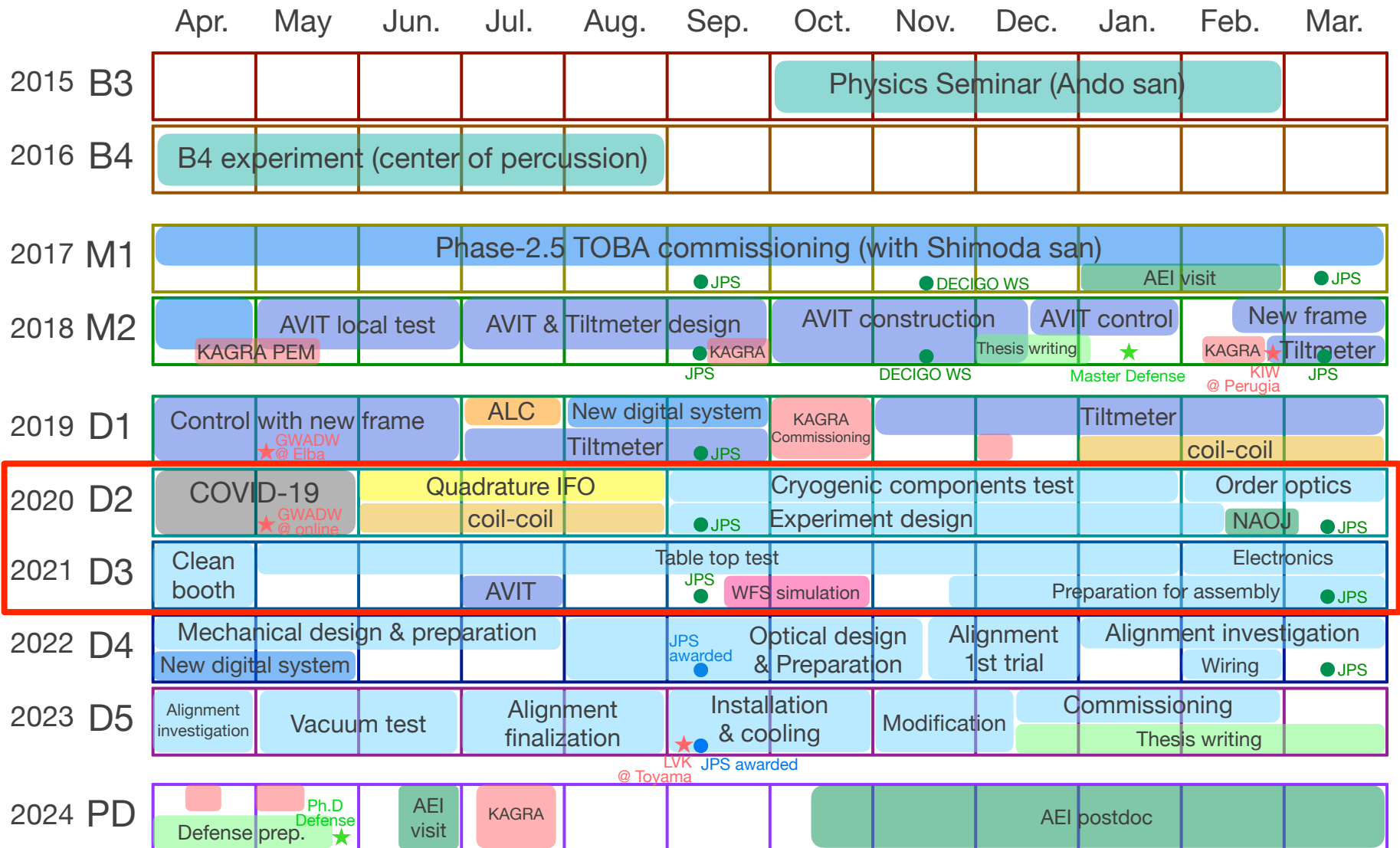
- Joined commissioning work before O3
 - Main person: Nakano san
 - Sub: Kokeyama san, Ushiba san, Izumi san
 - Enomoto san was in Hongo at that time to write his Ph.D thesis
- After one week later I came there, Nakano san was absent for two weeks
 - Nobody couldn't lock the interferometer
 - Took two weeks for recovery, just before Nakano san came back
 - ▶ Wasted entire two weeks...
- This was the first time to control a huge interferometer
- I was recognized by KAGRA people well



Research topic for Ph.D thesis

- Gradually started to think of research topic for my Ph.D thesis
- Actually, Ohashi san asked me to work in KAGRA and write my thesis about it
 - I refused it because I was too nervous and too bold
 - **I strongly regret to refuse this opportunity**
- After came back to Tokyo, still thinking about it, sometimes talked with Shimoda san
- No concrete plan, but wanted to improve the sensitivity of Shimoda san's setup

History of my research

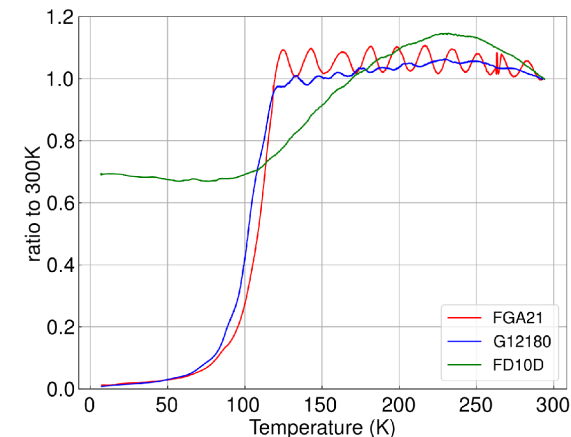
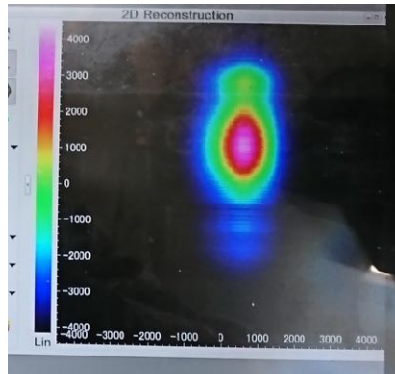
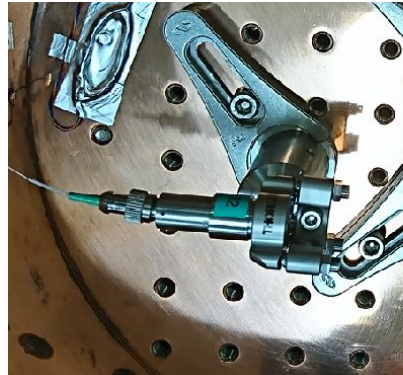


COVID-19

- At the beginning of FY2020 we couldn't enter the university **for 2 months**
- From June we resume the experiment
- Non-standard research life began
 - Nobody came to the lab except me
 - Online meeting, online seminar
 - Frustrated so much until Komori san came (~ 2 years)
- It was a good timing to consider what I would do for my thesis
 - ▶ Came up with **cryogenic monolithic interferometer**

Cryogenic test

- A lot of tests for cryogenic compatibility
 - Bonding
 - Collimator
 - Picomotor
 - PD
 - Metal & silicon
- I set up the environment around the new cryostat
 - Optical bench
 - Vacuum pump
 - Thermometer
 - Signal feedthrough
- Finally I handed over all of them to Ching Pin



Experiment in NAOJ

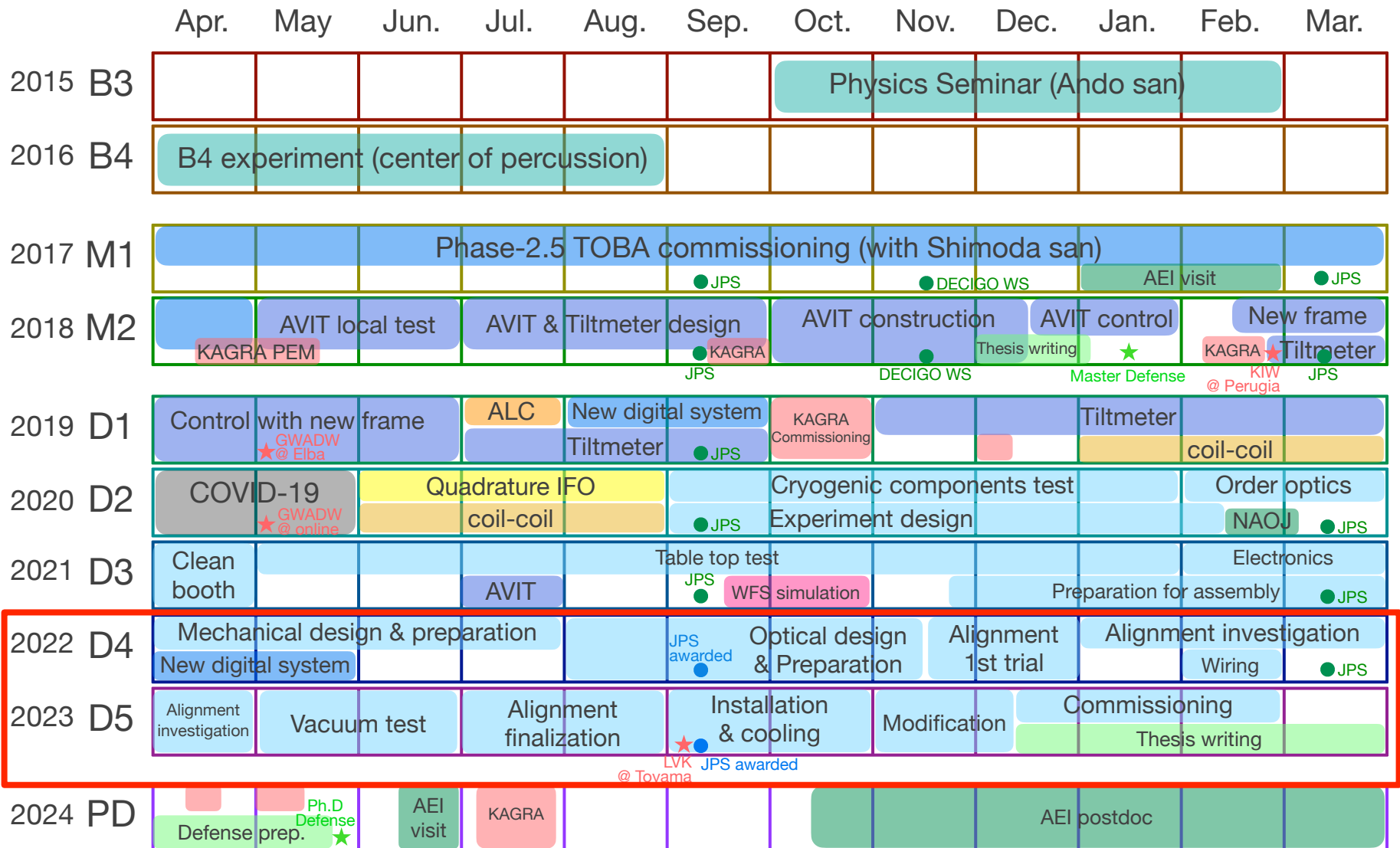
- For ALPS duty I had to go abroad or to some company for a long term
- I planed to visit ANU and join TorPeDO experiment, but cancelled it due to COVID-19
- Instead I visited NAOJ and did characterization of mirrors
 - Measured loss of the coating of a mirror manufactured by Sigma koki
 - Fused silica mirror + Ta/Si coating for 1550 nm
 - Design finesse: 10,000 → measured as **3,000**
 - ▶ Very lossy!
 - This experience was useful for designing optics for my experiment

Clean booth

Good space for assembling monolithic interferometer



History of my research



New digital system

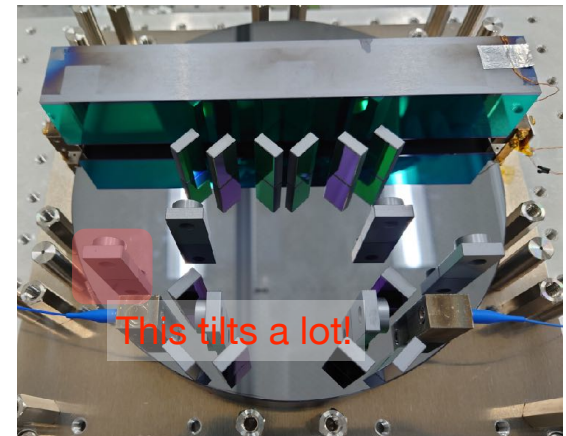
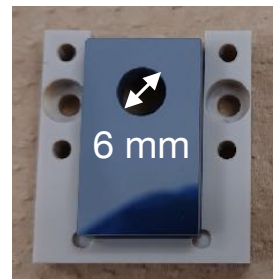
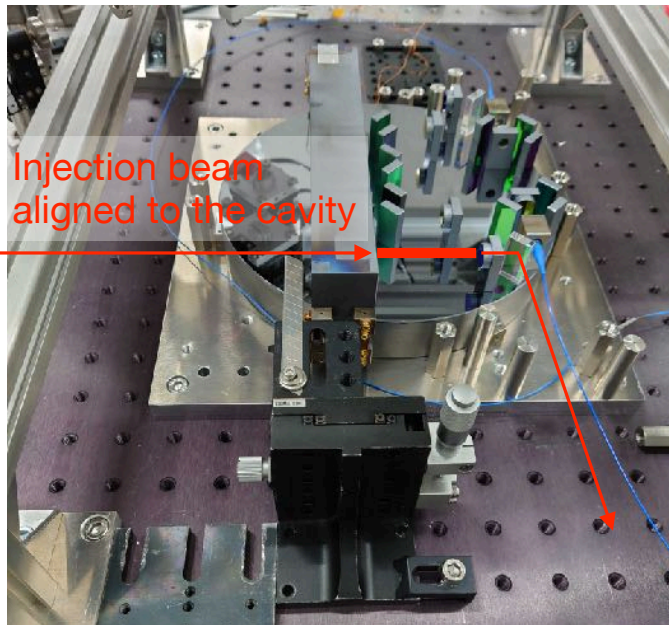
- Shimoda san and I wanted new digital system for TOBA for years
- First choice: SEAGULL
 - It was not suitable for our purpose in many points
 - We are really sorry for spending a lot of money for it...
- After visiting KAGRA, I planned to prepare a newer LIGO CDS for TOBA
 - Involving many people, started to implement a new system for DECIGO DPFP experiment
 - I hoped Ono kun would keep the knowledge of LIGO CDS after I left, but Ono kun left our lab earlier than me...
- ▶ **Crisis of losing know-how!**

Alignment trial

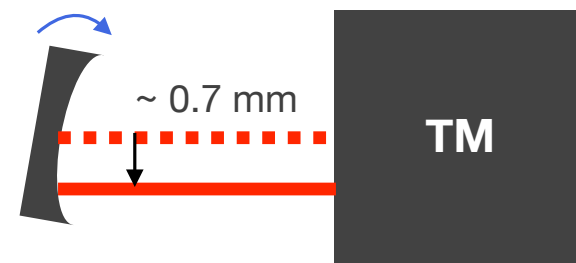
- So nervous to think about the alignment work
 - No way to remove it after bonding
 - Not so many spare components
- Even avoided thinking about the optical layout
- Finally started designing in 2022 August and ready for alignment in November
- Started alignment work from November
 - One of the most stressful days
 - I was afraid of making any mistakes
 - ▶ Actually it happened!

Alignment failure

- Beam seemed clipped at the aperture of one lens
 - Maximum mode matching ratio: 60 %
- Investigated the reason
 - ▶ One of the cavity mirror was tilted!
 - ▶ Tilted while curing the bonding?

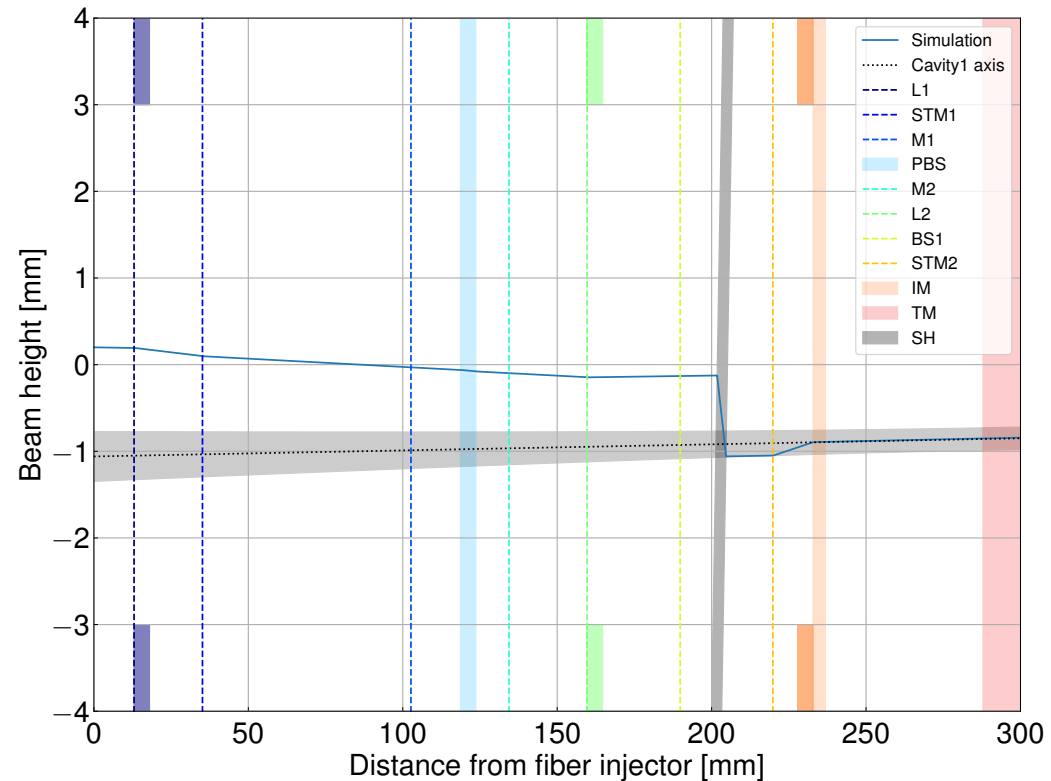
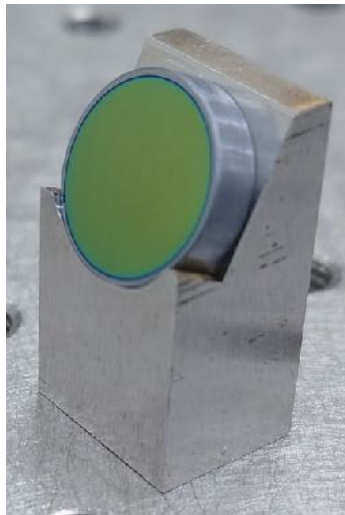
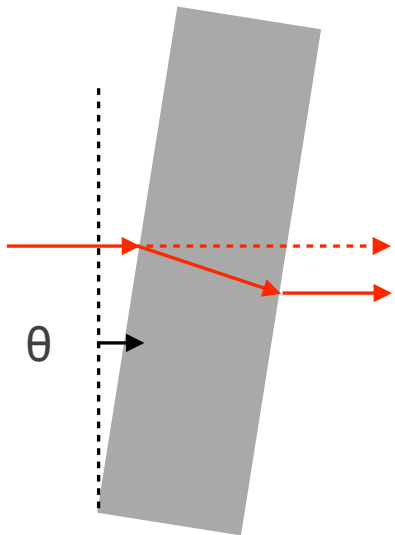


$\sim 4 \text{ mrad}$

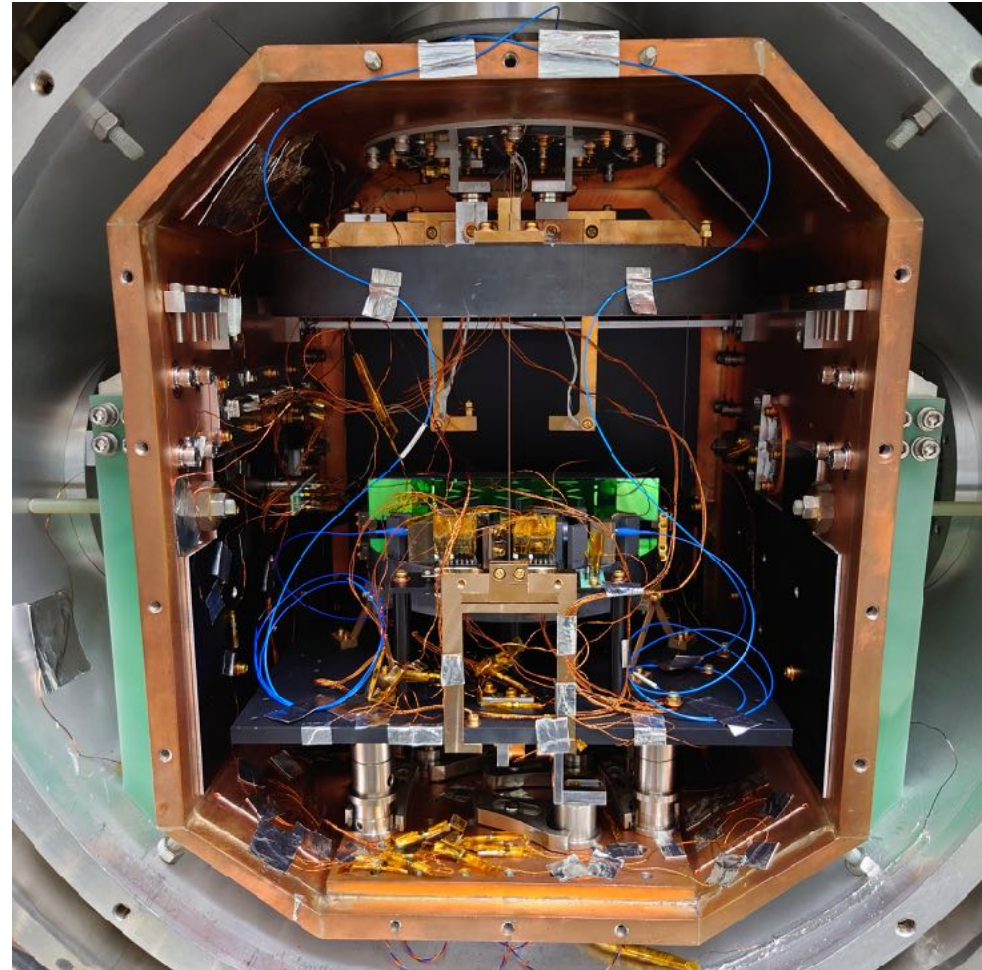
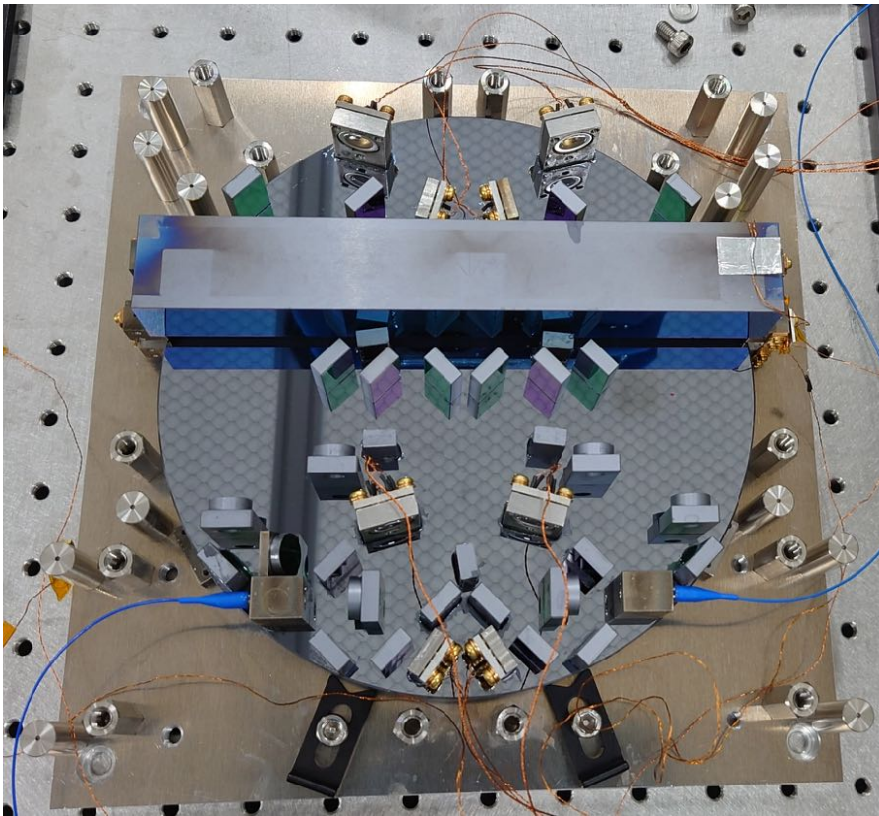


Alignment failure

- Finally solved by Ando san's idea
 - Put a beam shifter to get down the optical axis
 - Succeeded in achieving mode matching ratio > 95 %!

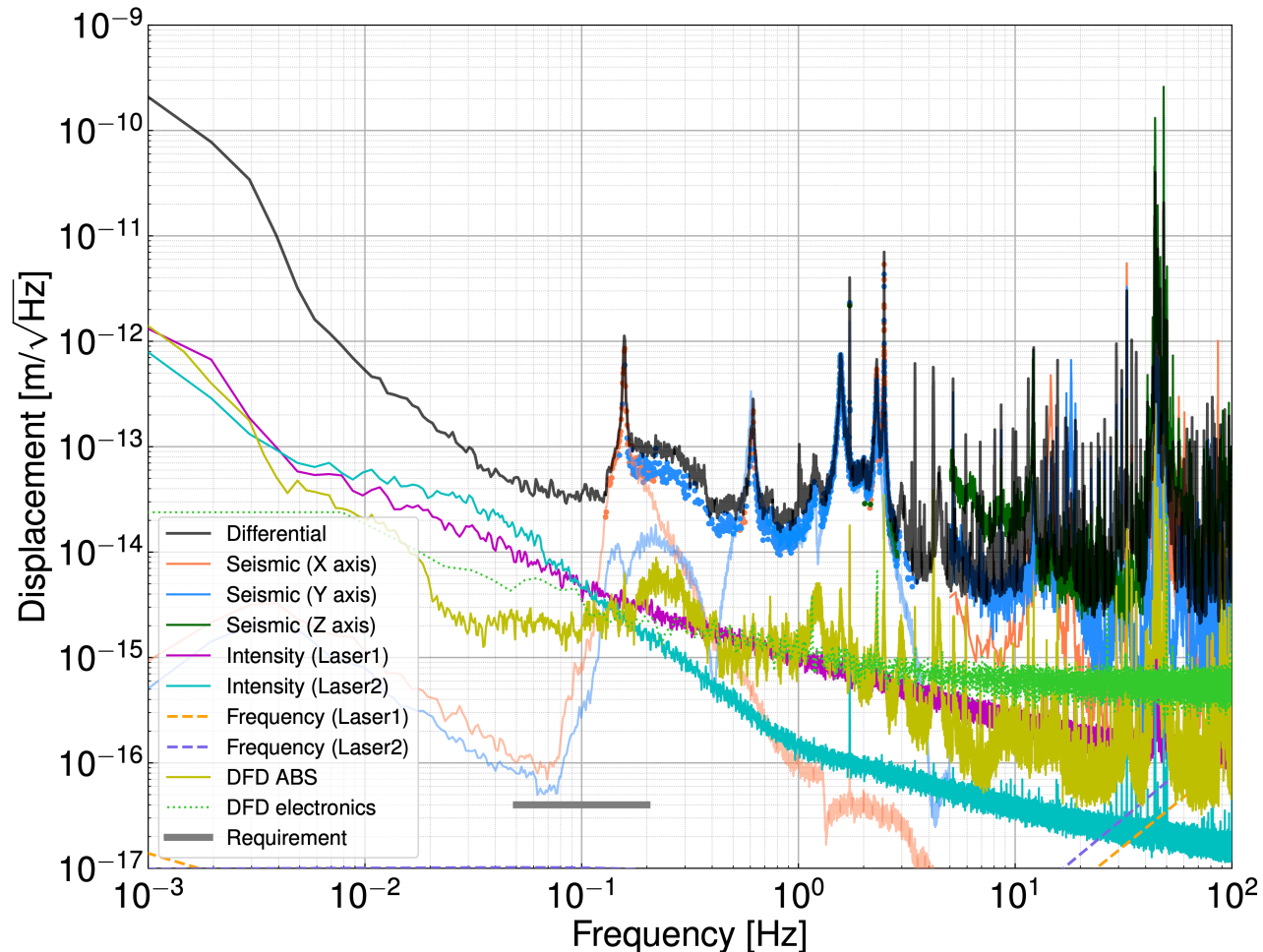


Monolithic interferometer assembled



Final results

Finally managed to take good data under a cryogenic temperature with great help of all of you!



Contents

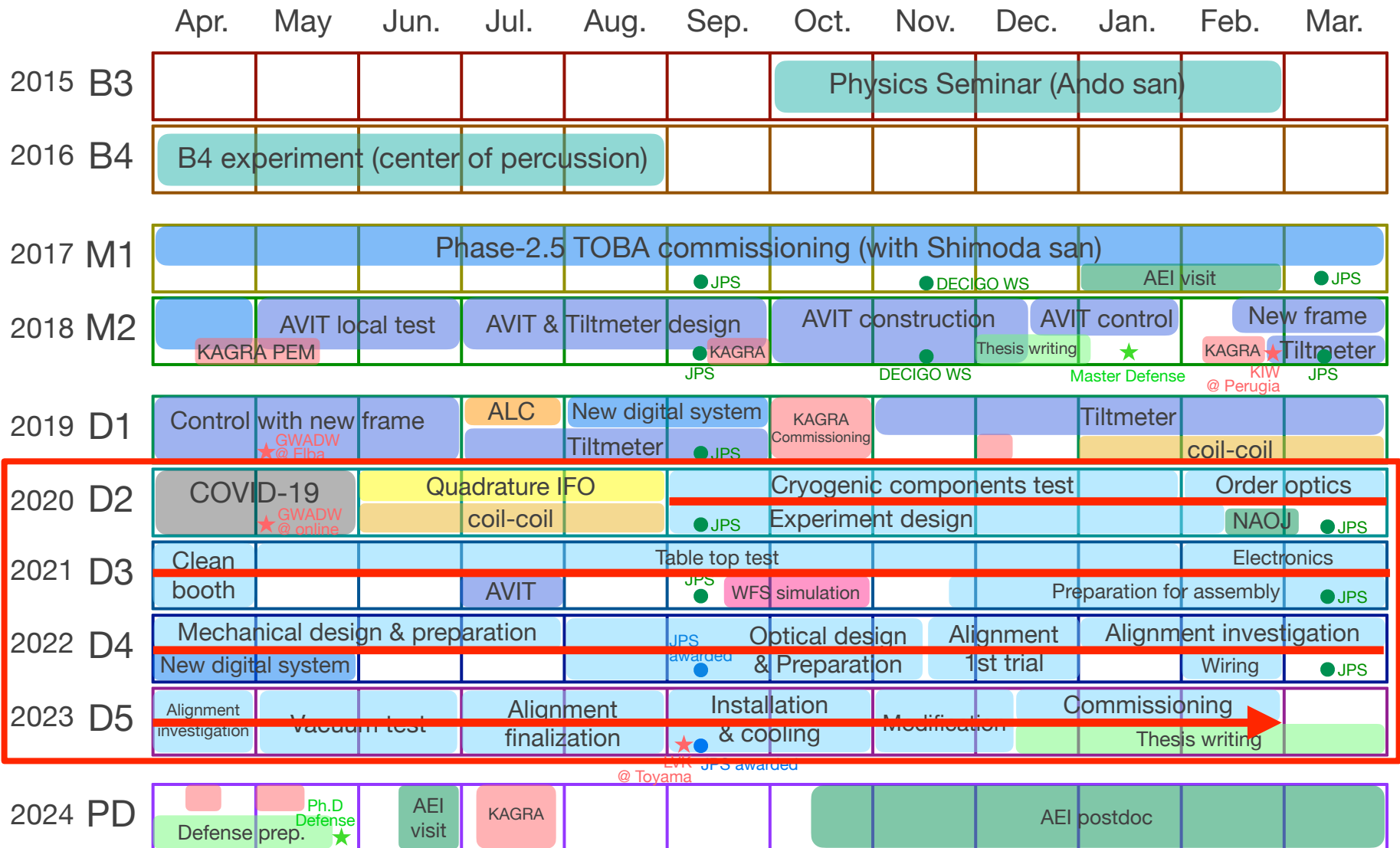
- Looking back on what I did
- **Random thoughts**
- What I will do in future

THE BEST THESIS IS...

RANK

- 1 A FINISHED THESIS
- 2 A FINISHED THESIS YOU SUBMITTED 2 MINUTES BEFORE THE DEADLINE
- 3 A FINISHED THESIS YOUR ADVISOR ACTUALLY READ
- 4 A FINISHED THESIS EXCEPT FOR ONE OR TWO MORE EXPERIMENTS (YEAH RIGHT)
- 5 A THESIS YOU DIDN'T ACTUALLY FINISH, BUT GOT AWAY WITH BY REWRITING THE SCOPE SECTION
- 6 A THESIS YOU SHOULD HAVE FINISHED BY NOW, BUT, YOU KNOW... LIFE.

History of my research



Why took so long?

- I took ~ 3.5 year to finish my work for thesis
 - Was I lazy?
 - ▶ Yes
 - Felt many stress due to life style after COVID-19
 - So afraid of failure when making monolithic interferometer
 - Gradually lost passions for my research for some reasons
 - ▶ No
 - Nobody is expert of monolithic interferometer around us
 - I did my work about monolithic interferometer alone
 - Simply difficult work technically

Why took so long?

- What should I have done to do it faster?
 - Ask help of other people more frequently
 - ▶ Sometimes Oshima san helped me
 - ▶ One person who basically always followed me (like Shimoda san and me when I was M1)
 - ▶ Good for training of each other and taking over the work
 - Open to others
 - ▶ I didn't want to show my work before finalizing it
 - ▶ No chance to notice mistakes
 - ▶ Regular meeting (per one/two weeks?)
 - ▶ External reviews for experimental design
 - Keep motivated
 - ▶ Something encouraging me
 - ▶ JPS awards helped me keep motivated

Why took so long?

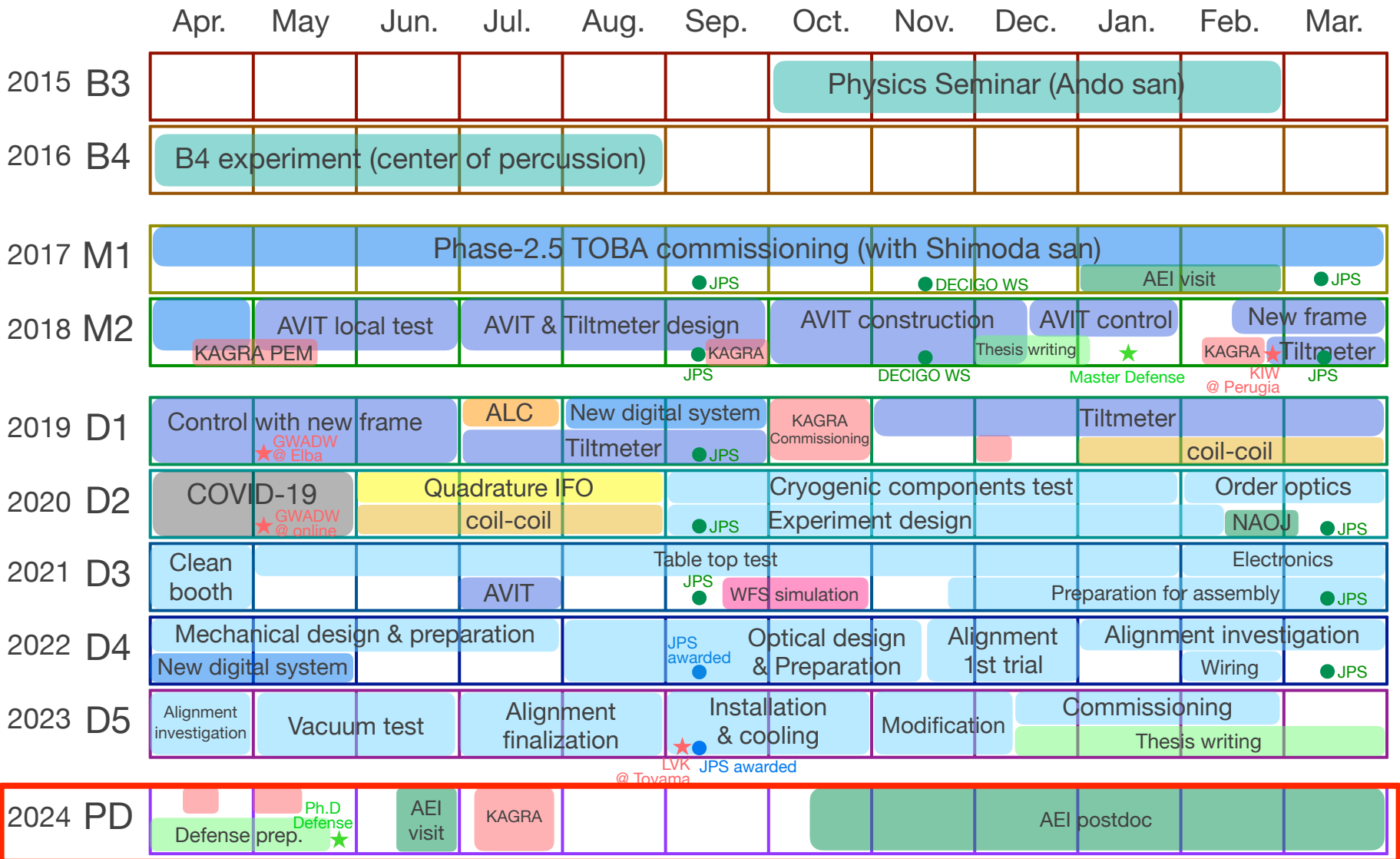
- What should I have done to do it faster?
 - Simply lack of the preparation
 - ▶ Before stating the work I should have consider a lot;
 - Can you imagine you will do this work for years?
 - Can you imagine you will finish your work?
 - Is your work valuable for the community?
 - Is there any science for your work? ...
 - Too late to decide the goal of the experiment
 - ▶ Should have stated my work 1 year faster
 - ▶ My opinion: if you graduate in 3 years, you should start your thesis work 2 years before the submission
 - **January of your D1 year**
 - As far as I know everyone follows this rule

Contents

- Looking back on what I did
- Random thoughts
- **What I will do in future**

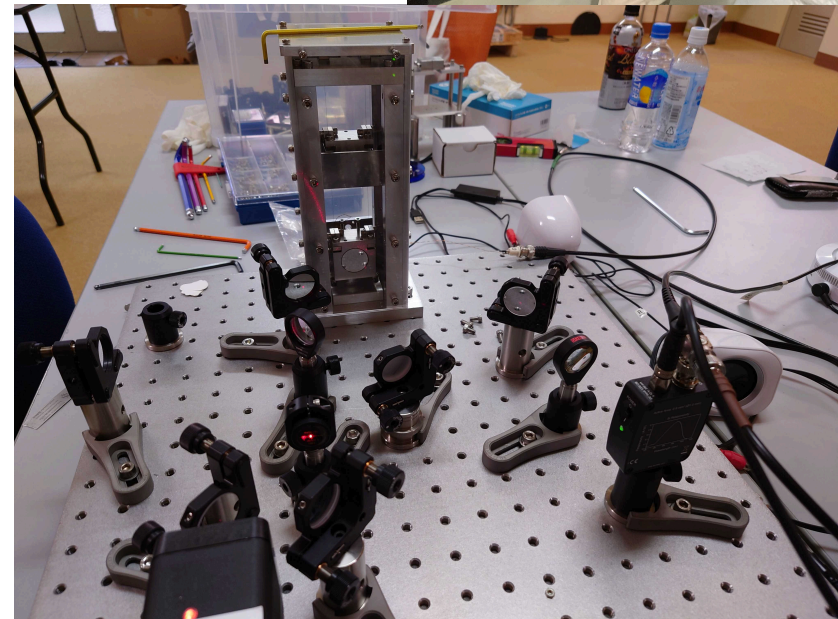
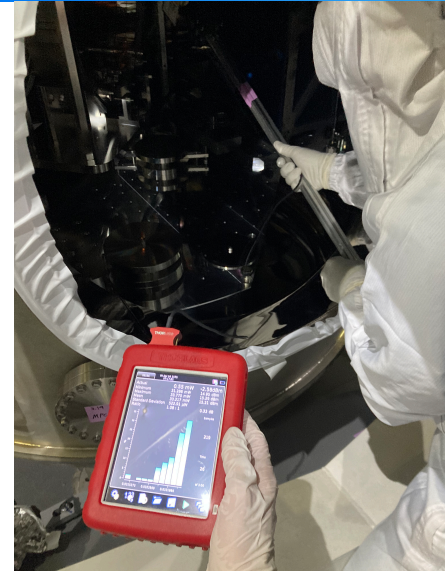


History of my research



After defense

- ~ September
 - Working on commissioning of KAGRA
 - ▣ BS reflectivity measurement
 - ▣ OMC commissioning
 - ▣ RFAM problem
 - ▣ Common mode servo issues
 - Supports of Somiya san's work
 - ▣ Outreach suspension
 - ▣ Setup of ASPIRE website
 - ▣ Taking care of people from Australia



After defense

- October ~
 - Working in AEI, 10 m prototype experiment
 - ▶ **Achieve SQL-limited interferometer**
 - Installation work for full interferometer (FPMI + BHD)
 - Commissioning work
 - Future plan (experimental ideas after reaching SQL, ...)
 - Preparing for starting my job abroad
 - Visa
 - Tax payment
 - **Apartment** (most difficult!)

Summary

- I was so happy to join Ando lab
- I hope I left you something special
- I wish good luck to all of you!

7年間ありがとうございました