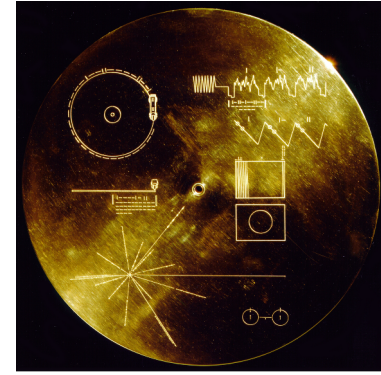


# LIGO VOYAGER: Wavelength Choice



GORDON AND BETTY  
**MOORE**  
FOUNDATION  
**Caltech**

Aidan Brooks  
for the Voyager team

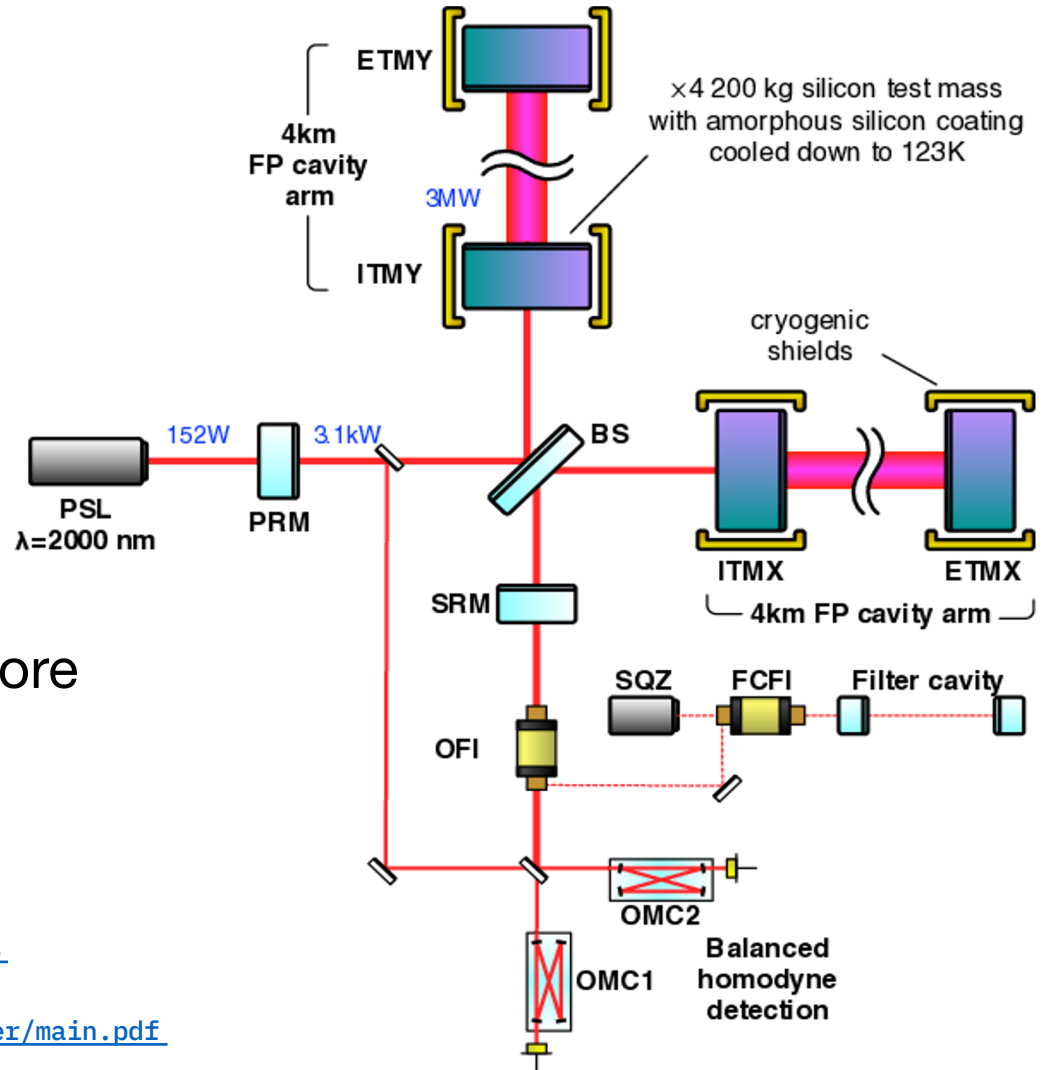
G2102043-v2



image: Eddie Sanchez

# Voyager

1. ~100x increase in rates
2. Intermediate step on the way to Einstein's Explorer network
3. Less cost than Adv LIGO
4. Re-use most of LIGO parts
5. Don't be afraid of cryogenics before you try it.



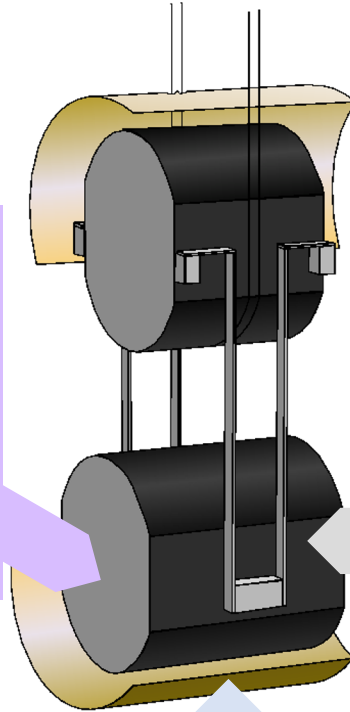
Science Metrics Paper: <https://doi.org/10.1088/1361-6382/ab3cff>  
Instrument Paper: <https://doi.org/10.1088/1361-6382/ab9143>

'Living' whitepaper: <https://docs.ligo.org/voyager/voyagerwhitepaper/main.pdf>

# CORE IDEAS

## ① Amorphous silicon coating

- Reduces thermal noise. Prospect of a **4-7x** reduction from aLIGO level
- Favors **2  $\mu\text{m}$**  wavelength



## ② Crystalline silicon substrate

- Improves quantum noise. **200 kg** mass, **3 MW** power
- High thermal conductivity, ultra-low expansion at **123 K**

## ③ Radiative cooling

- Still efficient at **123 K**
- Suspension design not constrained by cryogenics

# –Wavelength choice

*Choice of Laser Wavelength*

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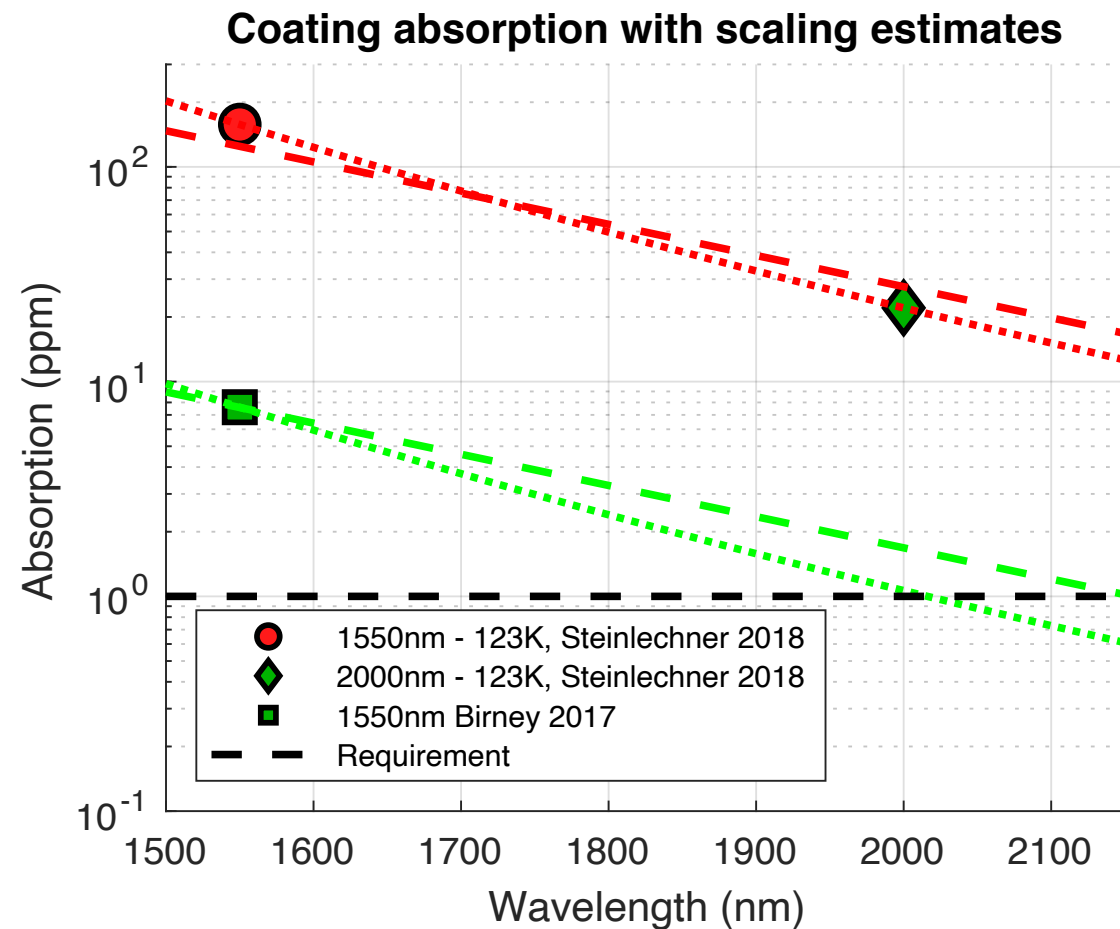
Consideration	Wavelength			
	1550 nm	1900 nm	2000 nm	2128 nm
Photodiode Q.E.	> 99%	≈ 87%. Promising trajectory (Section 5.4).		
Coating thermal noise	Low	≈14% larger		
Optical scatter loss	66% larger	Low		
Residual gas noise	low H <sub>2</sub> O	some H <sub>2</sub> O	low H <sub>2</sub> O	
Coating absorption	High	Medium		
Si substrate absorption	Increases as $\lambda^2$ but not dominant effect			
SiO <sub>2</sub> substrate absorption	< 1 ppm/cm	20 ppm/cm	40 ppm/cm	120 ppm/cm
Angular instability	Less stable	More stable arm cavity		
Parametric instability	Very little change with wavelength			

**TABLE 3:** Summary of wavelength considerations

From Voyager instrument paper <https://arxiv.org/abs/2001.11173>

## — Coating absorption favors longer wavelength

- Requirement for absorption
- **Set by heat budget**
- Can extract about 10W via radiative cooling
- Too much absorption limits stored power OR raises temperature



# Absorption in fused silica favors shorter wavelength

- Multi-phonon absorption
  - Fundamental process in fused silica
  - Rises steeply above 2 $\mu\text{m}$

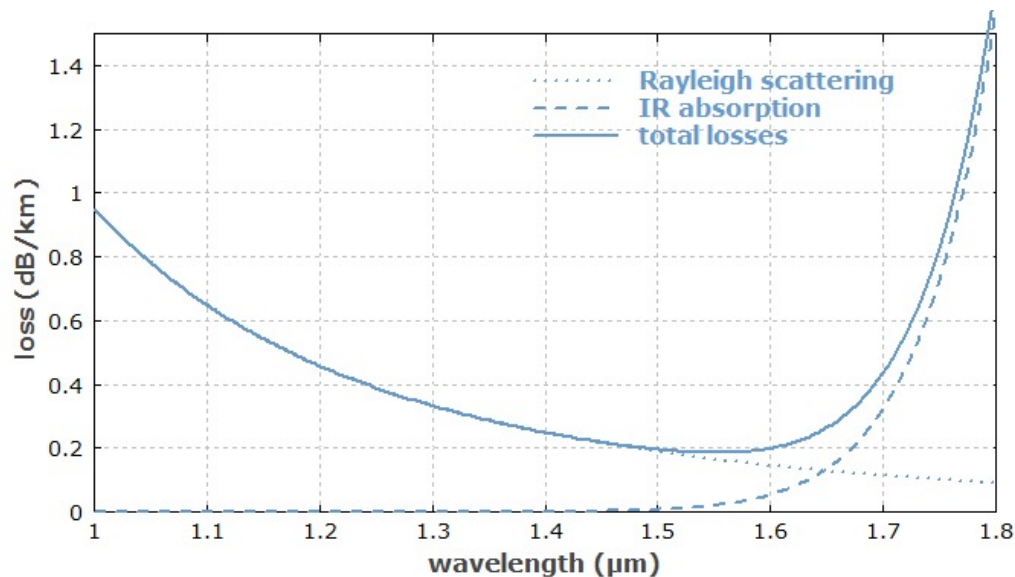
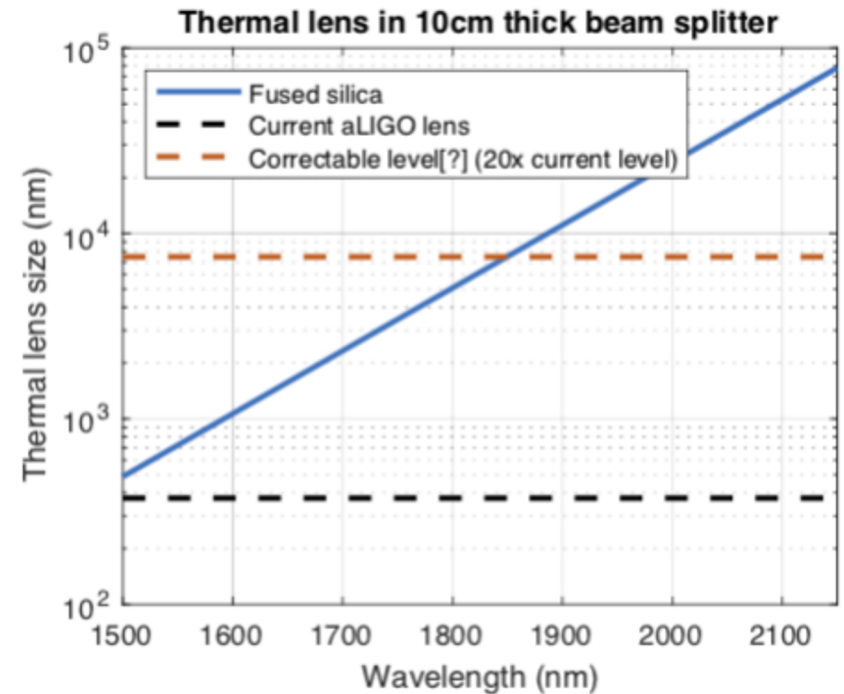


Image credit: RP Photonics Encyclopedia



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# Mariner-40m: Voyager prototype

## HAVE

- A Voyager prototype in the CIT-40m lab
- 2-phase approach:
  - Phase I: cryo FPMI
  - Phase II: ~Voyager
- Silicon optics
- 123 K operation
- **2128nm PSL**
- DRFPMI + ALS + BHD
- ~~Single~~ double stage suspensions
- 1.4 micron ALS

## HAVE-NOT

- No Quad Suspensions
- Passive stack: no ISI
- ~100x lower power
- Smaller beams
- No TCS
- No filter cavities
- Maybe some squeezing?

## Two micron lasers - options

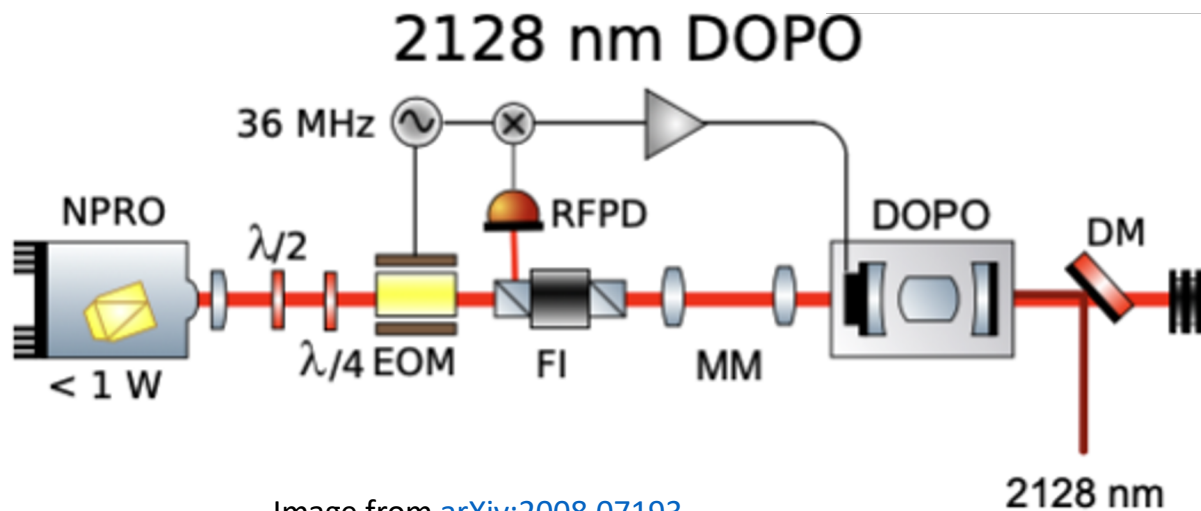
- Parametric down-conversion to 2128nm
- ECDL is an option ([2um article](#))
- Laser diodes (around 2000nm)

## 2128nm DM LASER

EP2128-DM-B - Preliminary



Eblana Photonic  
tive, highly cohe  
discrete-mode  
linewidth perform  
applications.



# — Voyager Research Opportunities

1. 35 W laser amplifier for 2 microns
2. EOM for 2 microns with resonant modulation capability and a 35 W power handling capacity
3. low absorption glass to meet the BS requirements
4. process to anneal large pieces of silicon to trap the Oxygen and lower the 2 micron absorption coefficient to 5 ppm/cm.
5. low noise, low absorption HR mirror coating for 2 microns
6. ALS (1.4-3 microns, phase locked with carrier)
7. High QE Photodiode for 2 microns
8. How to handle the ice formation on the HR surfaces of the mirrors?
9. Damping of Parametric Instabilities: beyond the "Mushrooms" approach
10. 2-micron squeezer (10 dB measured in a homodyne detector)
11. Quadruple Suspension
12. Seismic Isolation Platform
13. Optical Rigid Body: lock all platforms with lasers
14. Dynamic RoC actuator for test masses
15. UHV compatible 2um Faraday isolator

# Components for Mariner

