Super Conducting Radio-Frequency photoinjector

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Outline

- Motivation
- All Nb SC RF photoinjector
- Gun cavity
- Niobium cathode
- Other components
- Beam parameters and Time line

Motivation

Requirements of electron beam with

both

high brightness (low emittance, high charge)

and

high average current (high duty factor)

- E-cooling
- PERL

RF photoinjector

- Photoemission

Laser ⟶ Photocathode (Φ, QE)

high density charge, short bunch length beam

- RF acceleration

High gradient => low emittance beam

=> high brightness

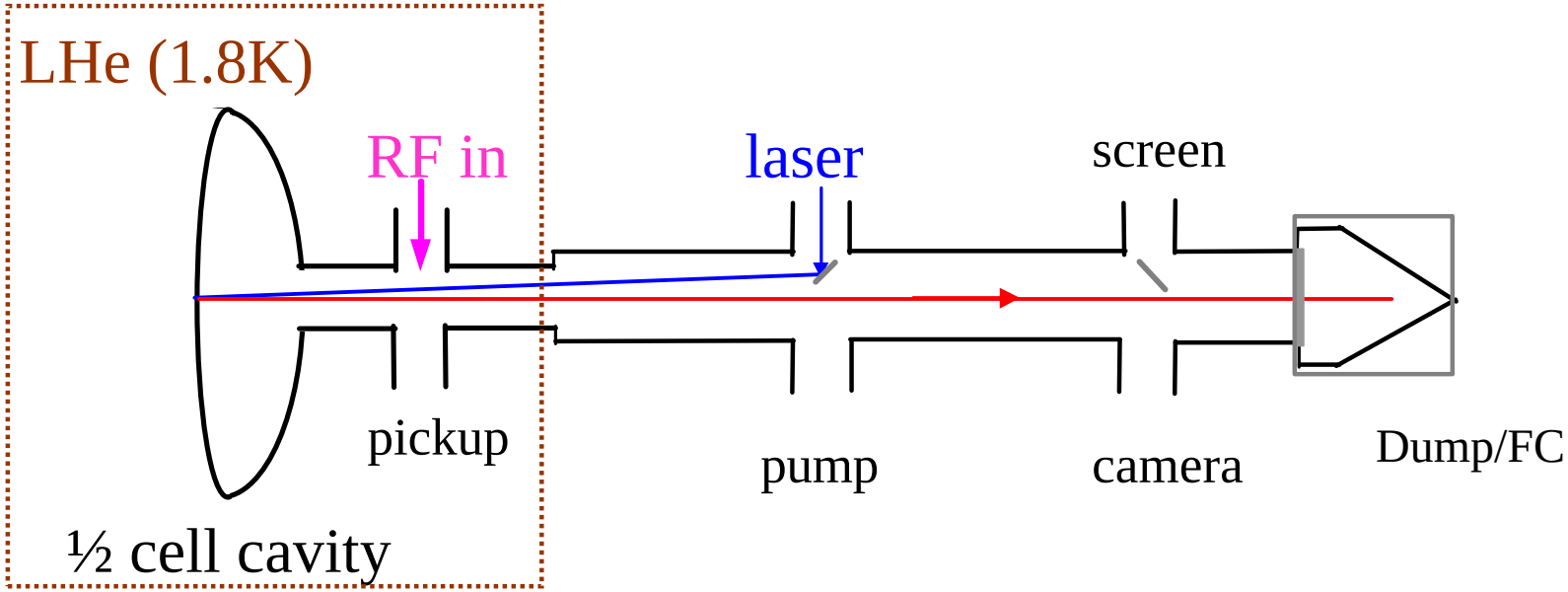
SC RF acceleration

- Normal cavity - Copper (OFHC)
  surface current =>RF power loss
  => pulse mode

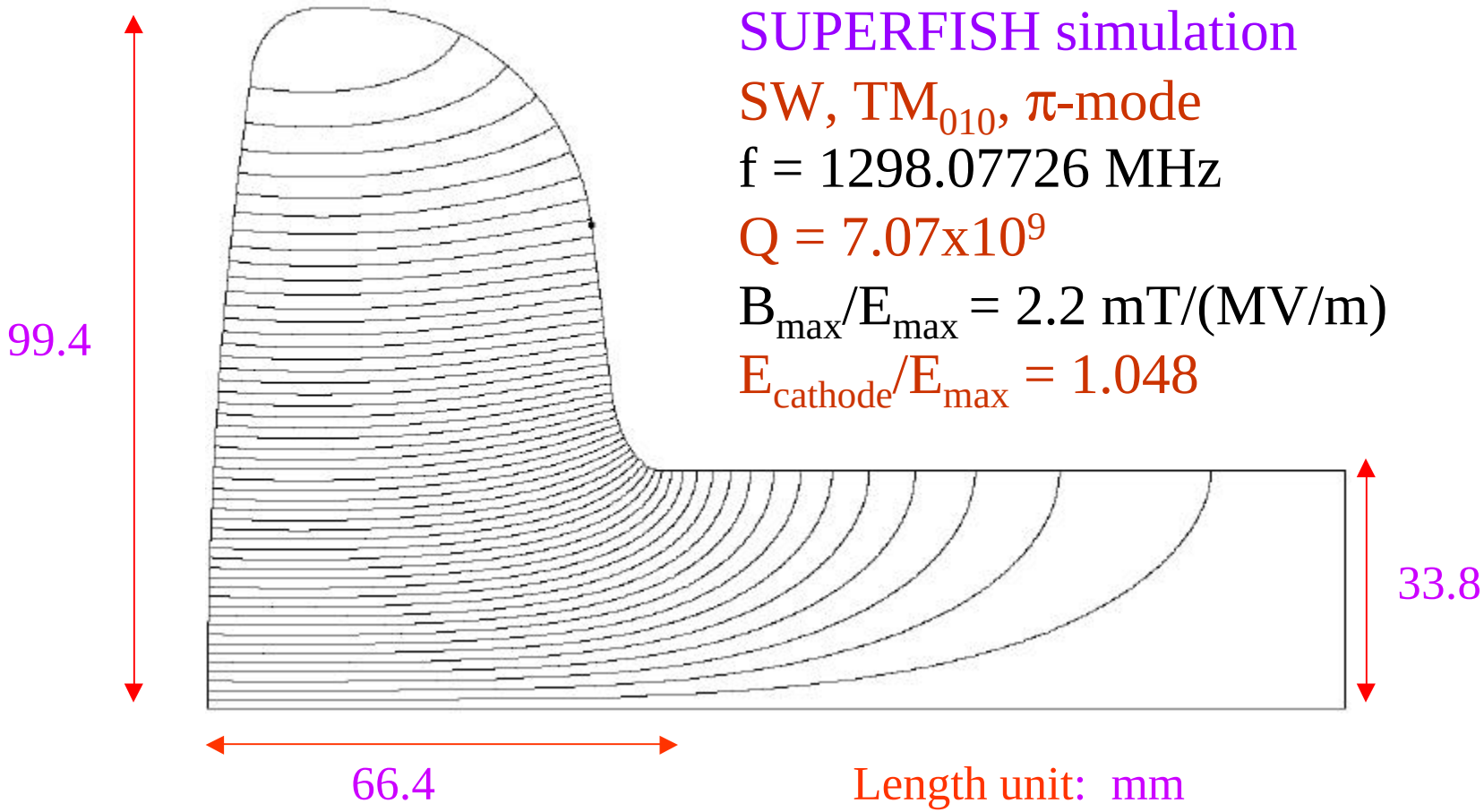
- Superconducting cavity - Niobium
  very low RF loss => CW operation
  => high average current

Schematic of SC RF gun

Cavity Nb itself as cathode



Cavity design



SUPERFISH simulation

SW, TM_{010}, π-mode

f = 1298.07726 MHz

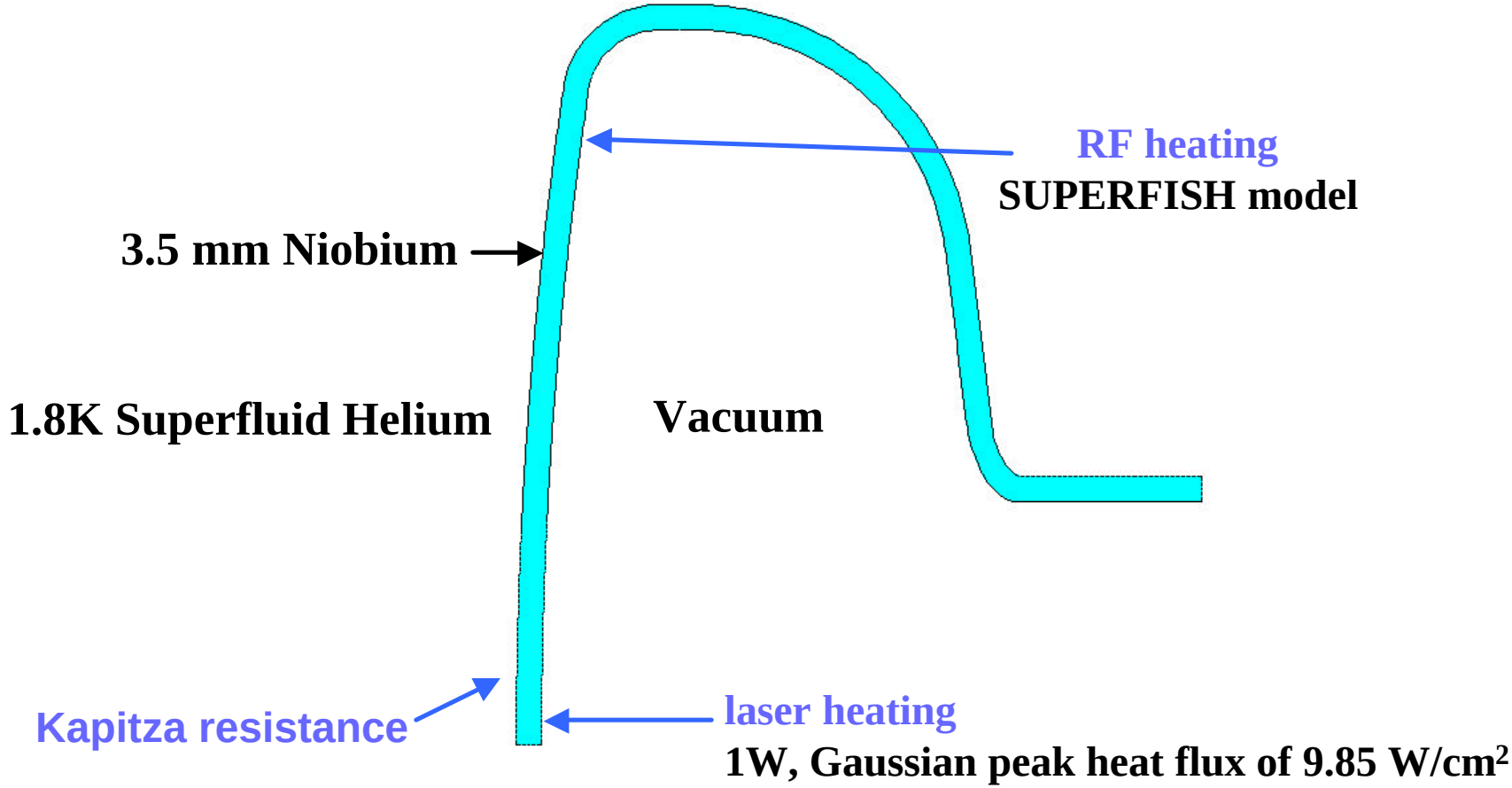
$Q = 7.07 \times 10^9$

B_{max}/E_{max} = 2.2 mT/(MV/m)

$E_{cathode}/E_{max}$ = 1.048

Length unit: mm

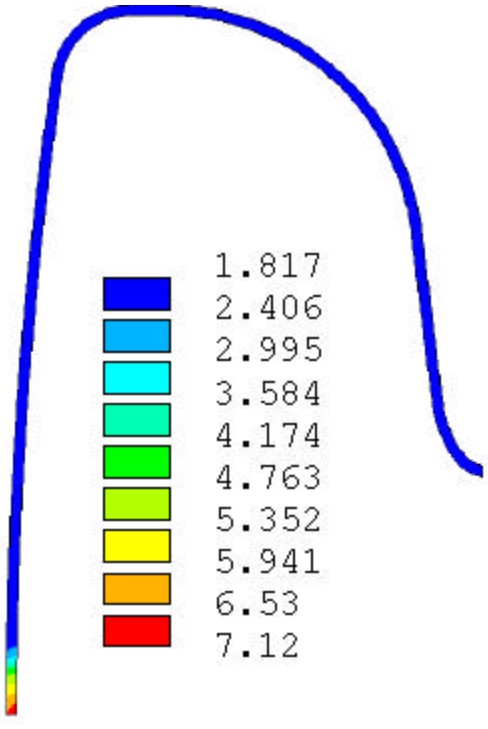
Cavity analysis



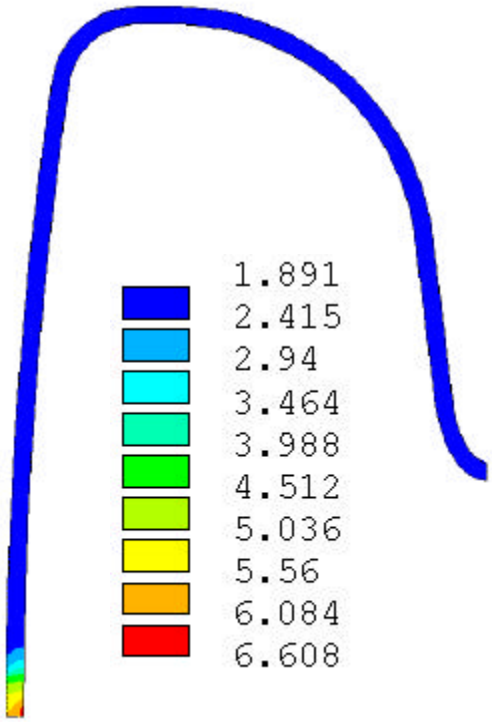
Thermal results

Wall Thickness vs. Temperature distribution

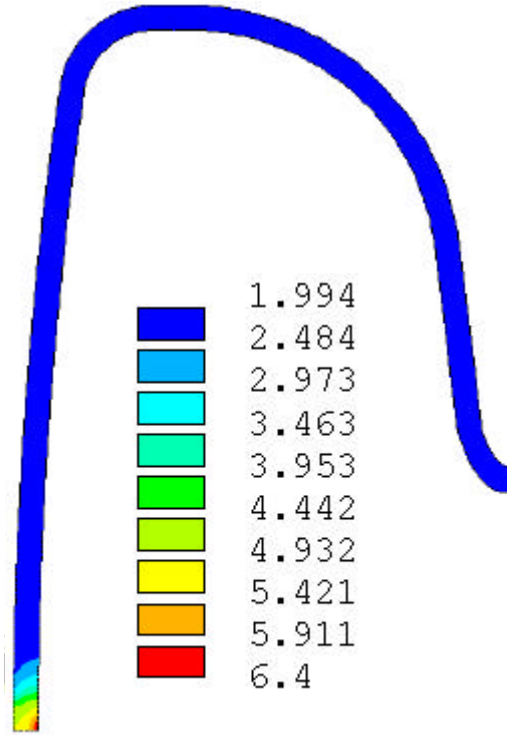
1.5 mm



2.5 mm



3.5 mm

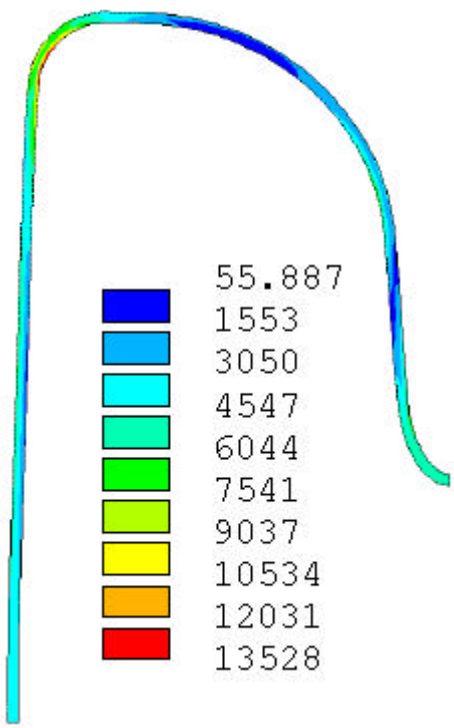


Temperature in K

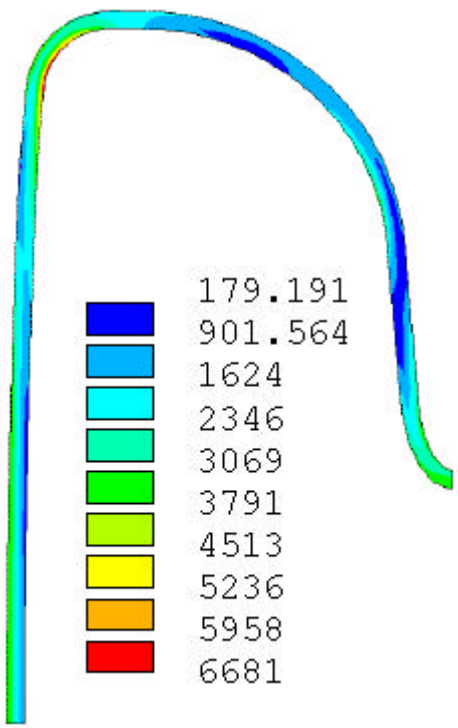
Structural results

Wall Thickness vs. stress/strain distribution

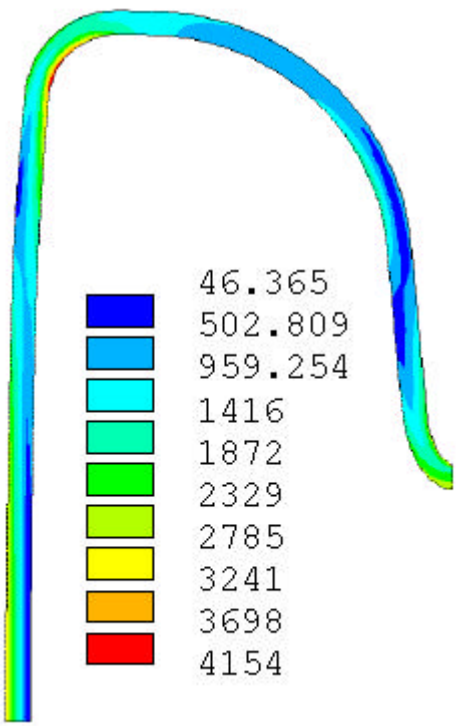
1.5 mm



2.5 mm



3.5 mm



Von Mises stress in PSI

Accelerating gradient

- Maximum gradient of Nb cavity determined by the RF critical magnetic field
- Theoretically ~ 55 MV/m
- Practically 25 - 43 MV/m
- Limitations: Electric field emission *and* thermal breakdown (quench)

Cavity preparation

- High purity Nb (RRR>200)
- Pre-cleaning

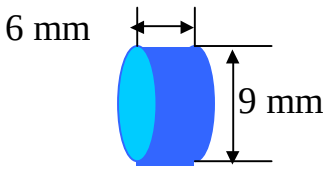
  ultrasonic detergent bath, DI water rinsing
- Polishing

  Buffered **C**hemical **P**olishing, **E**lectro **P**olishing
- Heat treatment @ UHV
- Light polishing
- High pressure water rinsing (100bar)
- Clean room assembling

Niobium cathode preparation

Machining

RRR=250



Pre-cleaning

Soapy water cleaning => DI water flushing

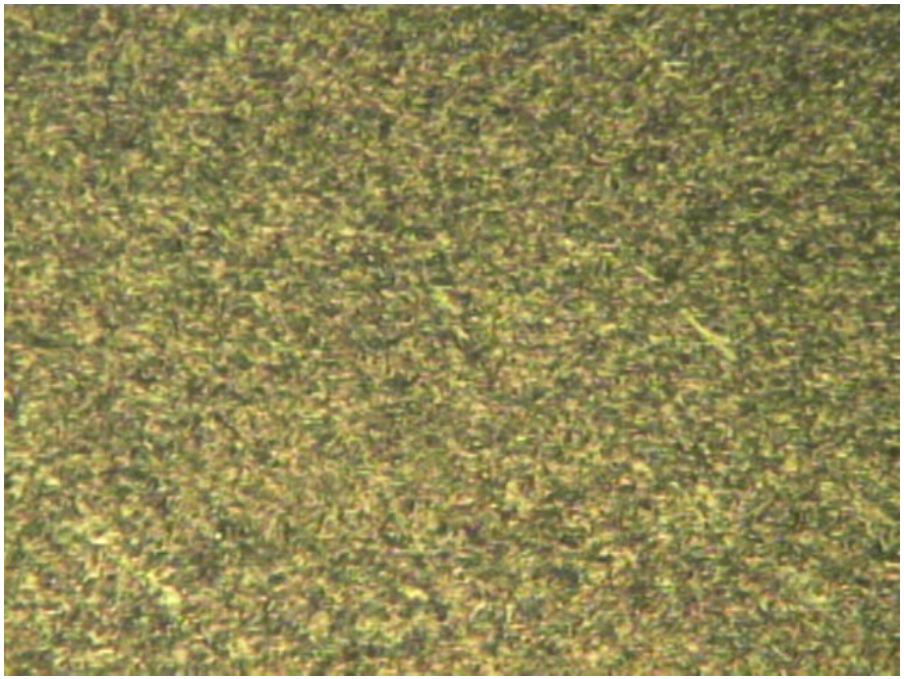
BCP etching

HF(48%,7.5 ml) + HNO_3(69.5%,7.5 ml) + H_3PO_4(85% , 15 ml)
At 10-12 °C for 20-30 min

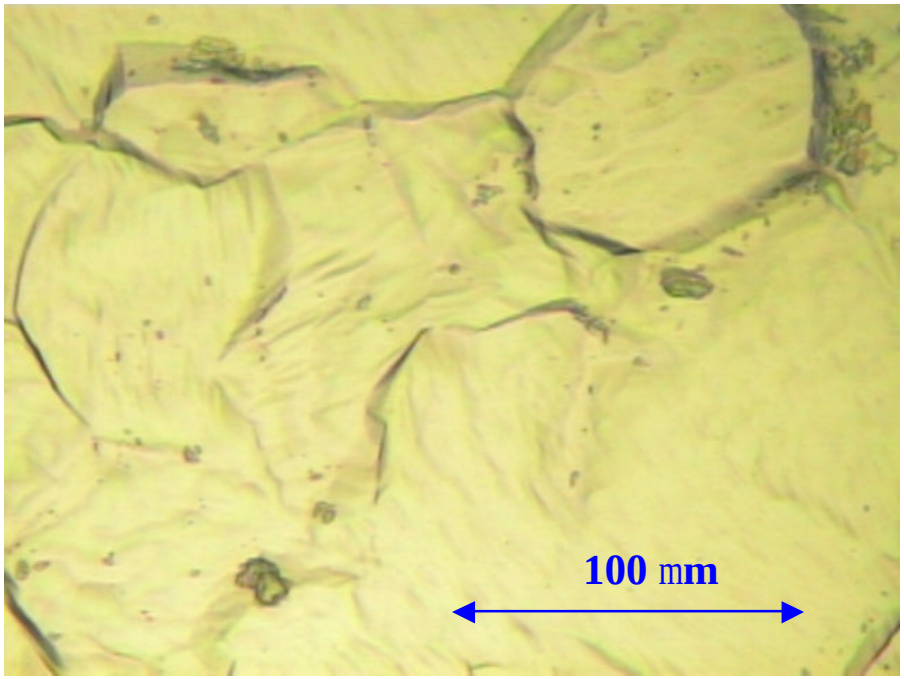
Post-polishing and cleaning

- 9, 6 and 1 micron diamond compound polishing
- Hexane bath ultrasonic cleaning
- High purity Nitrogen drying → vacuum

Surface of Nb sample

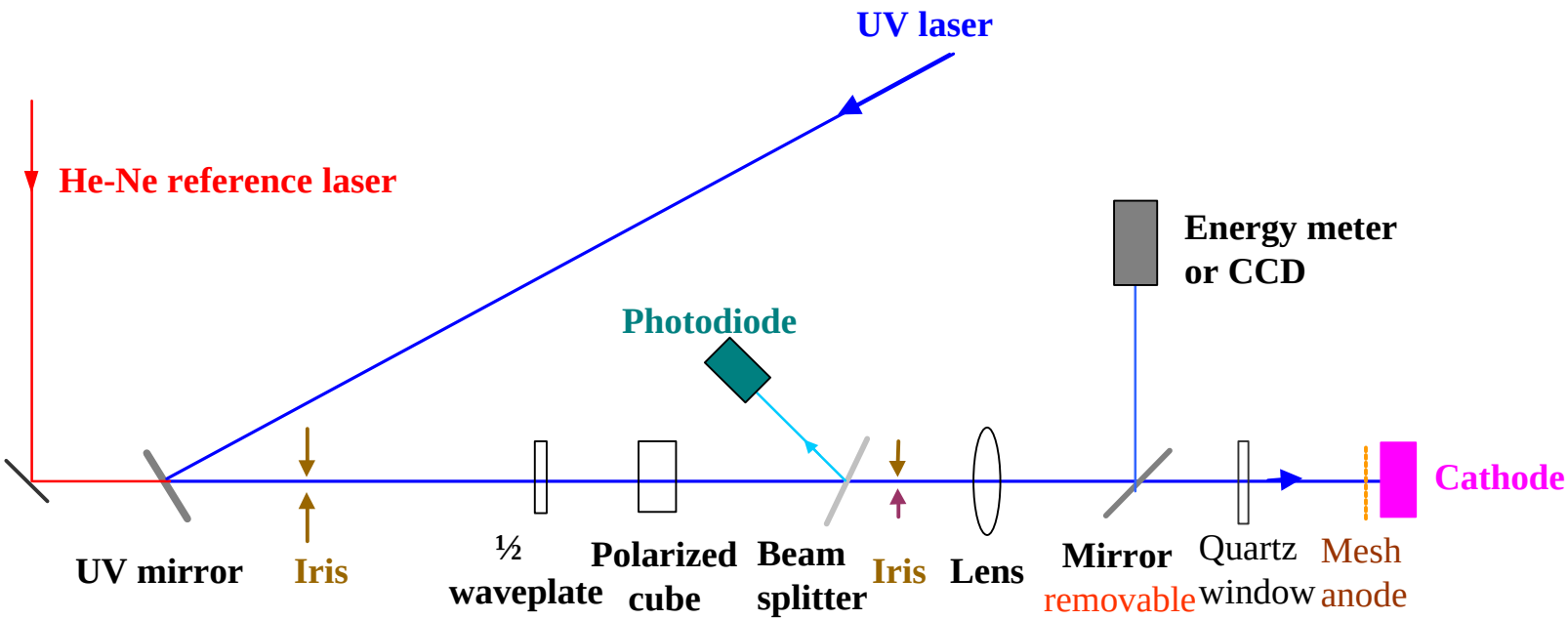


before BCP



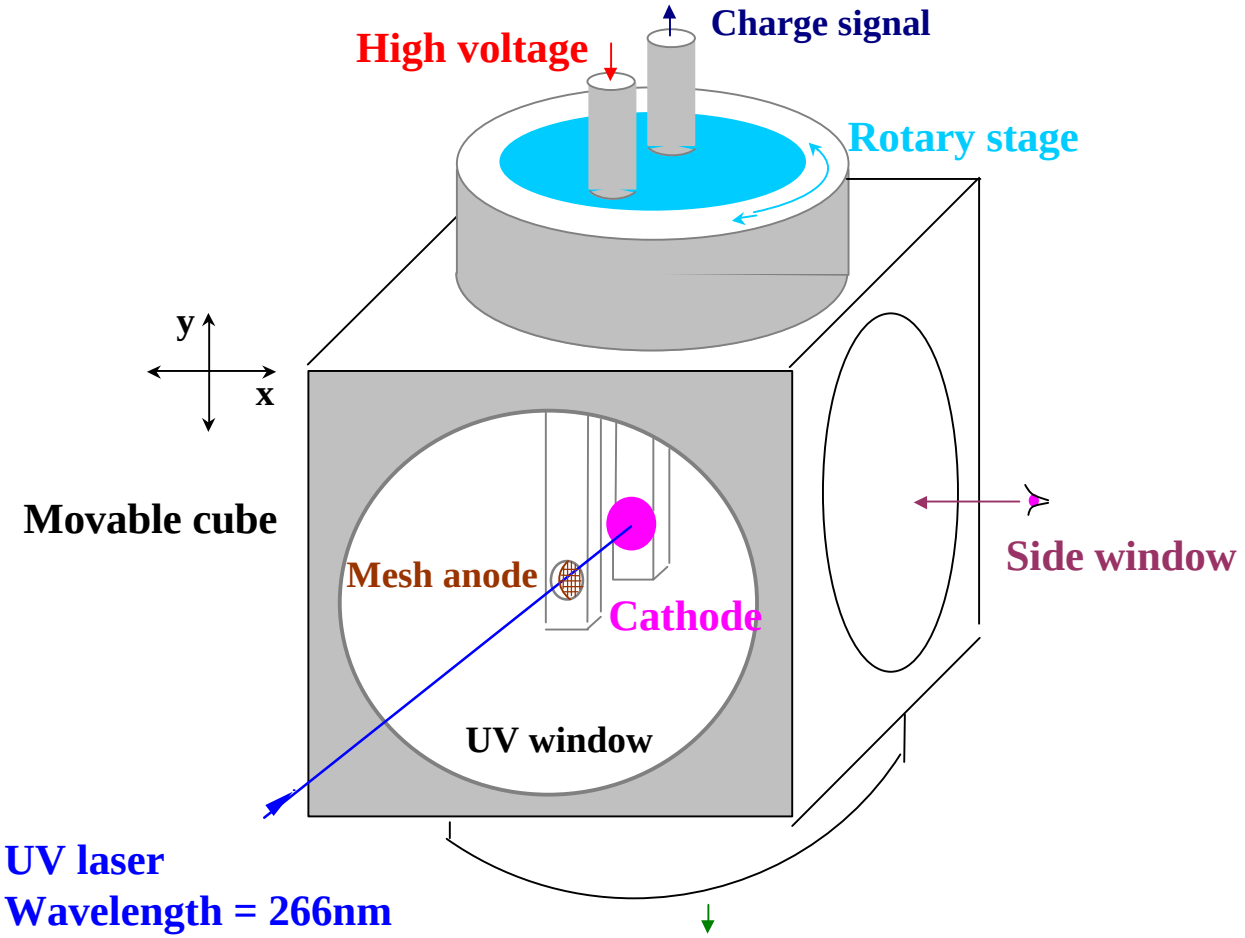
after BCP

Niobium cathode measurement



Optical set-up for QE measurement

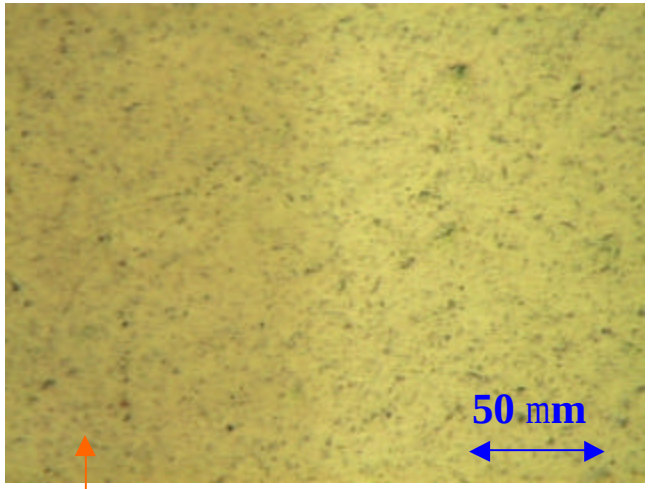
Vacuum chamber



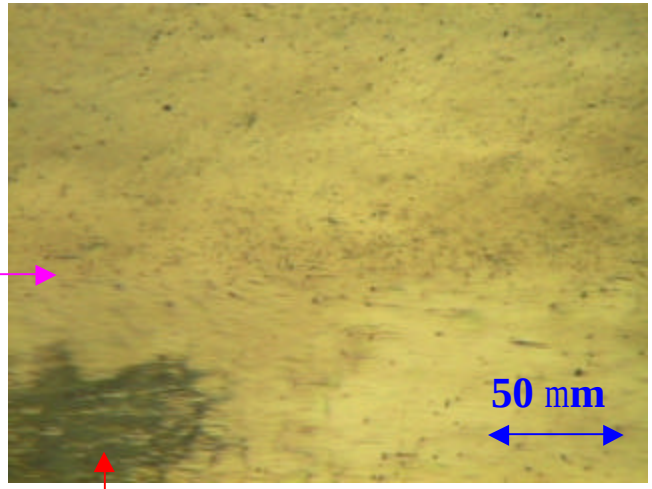
UV laser
Wavelength = 266nm
Pulse energy £ 1mJ
Pulse repetition = 10Hz
Pulse length » 15ps

Ion pump
~ 6´10^{-9} torr

Nb surface after different laser cleaning



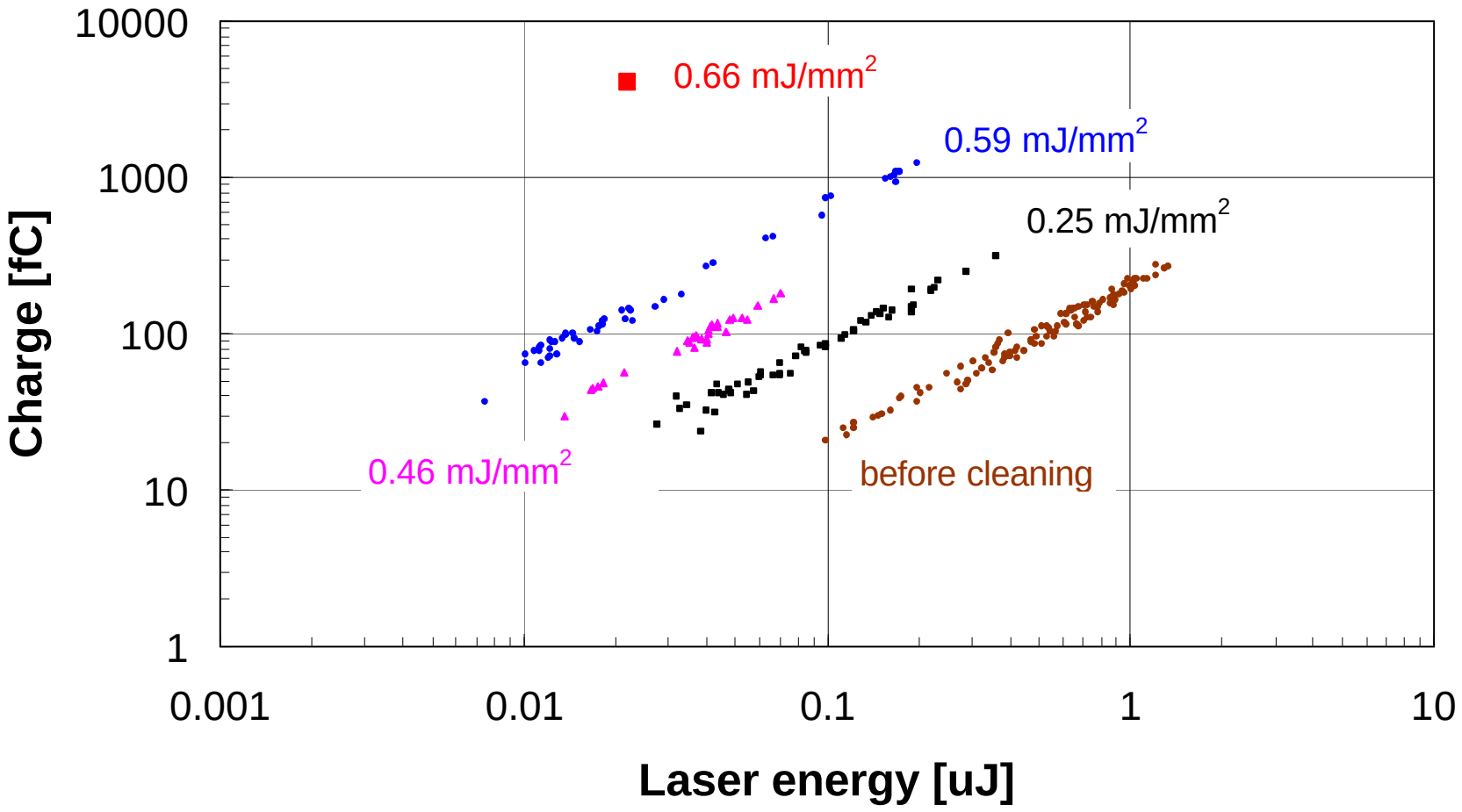
0.3 mJ/mm^2



0.8 mJ/mm^2

0.5 mJ/mm^2

Photoelectron charge vs. laser energy



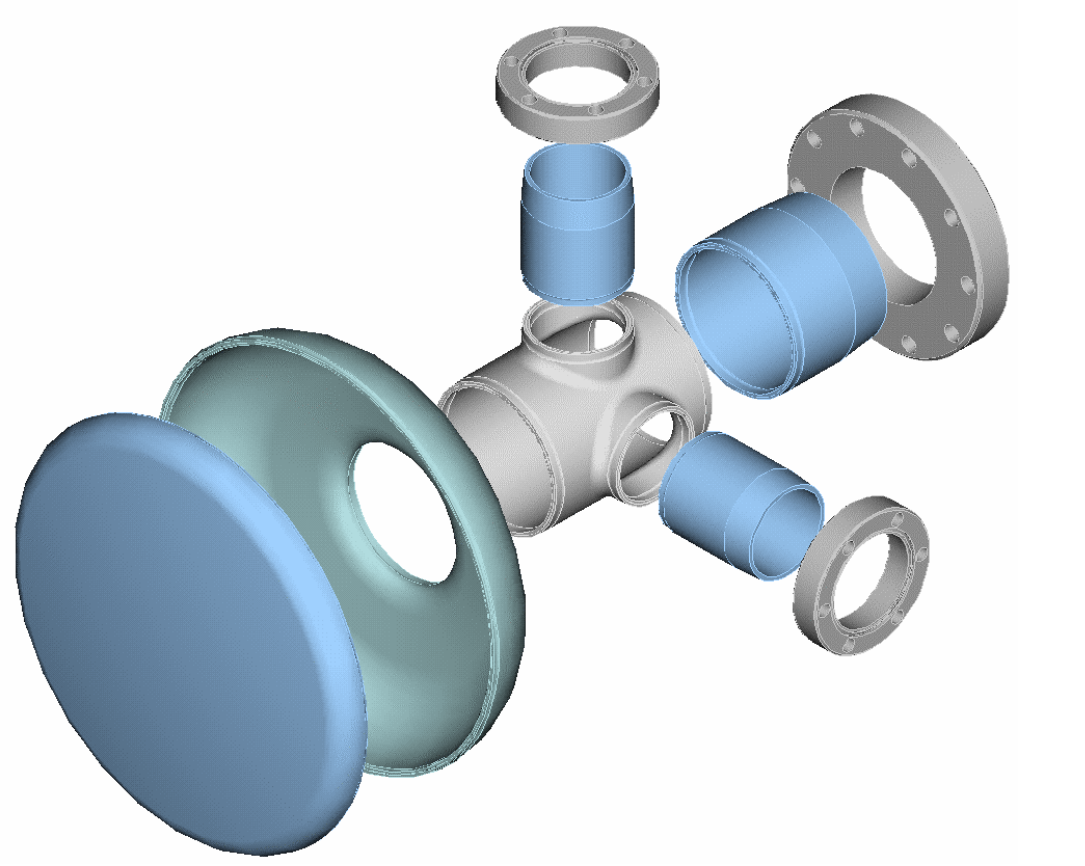
Measured Nb QE

Before cleaning	9.3×10^{-7}	2×10^{-6}	3×10^{-6}
~ 0.25 mJ/mm^2	4.0×10^{-6}	1.5×10^{-5}	1.5×10^{-4}
~ 0.4 mJ/mm^2	1.2×10^{-5}	3×10^{-5}	2.4×10^{-4}
~ 0.6 mJ/mm^2	2.9×10^{-5}	5×10^{-5}	8.3×10^{-4}

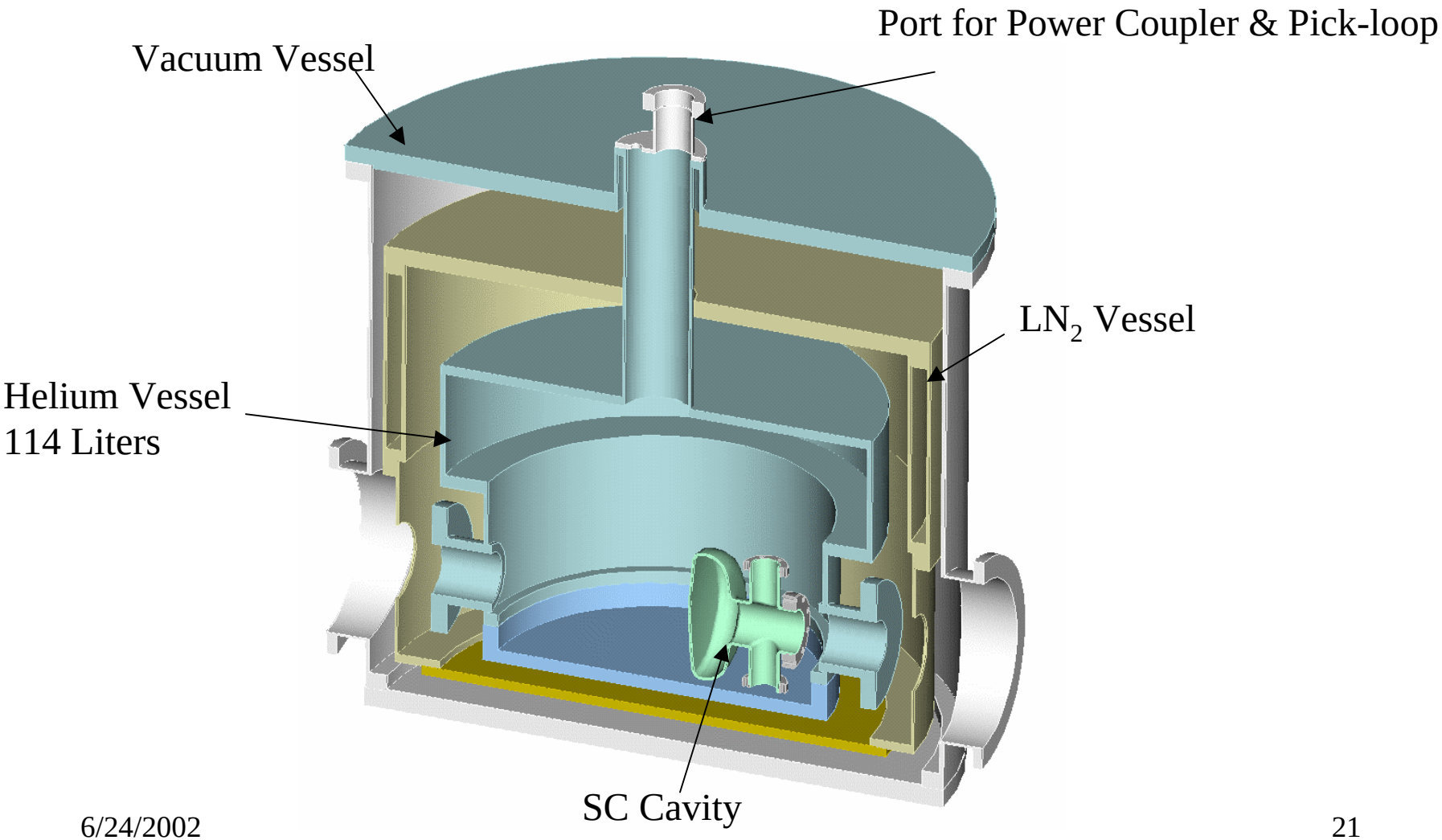
A. Fry et al. 8.5×10^{-7} *Rochester Univ. UR-1340 (1994)*

L. Hand et al. 3.2×10^{-6} *NIMA372(1996)335*

Superconducting Cavity

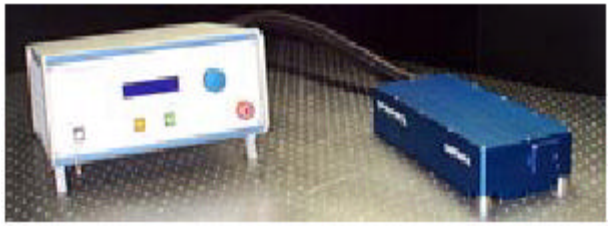


Cryostat


Port for Power Coupler & Pick-loop
Vacuum Vessel
LN_2 Vessel
Helium Vessel
114 Liters
SC Cavity

Laser CHEETAH-X-FHG

Time Bandwidth, Switzerland



Energy: ~ 1W @ 266 nm

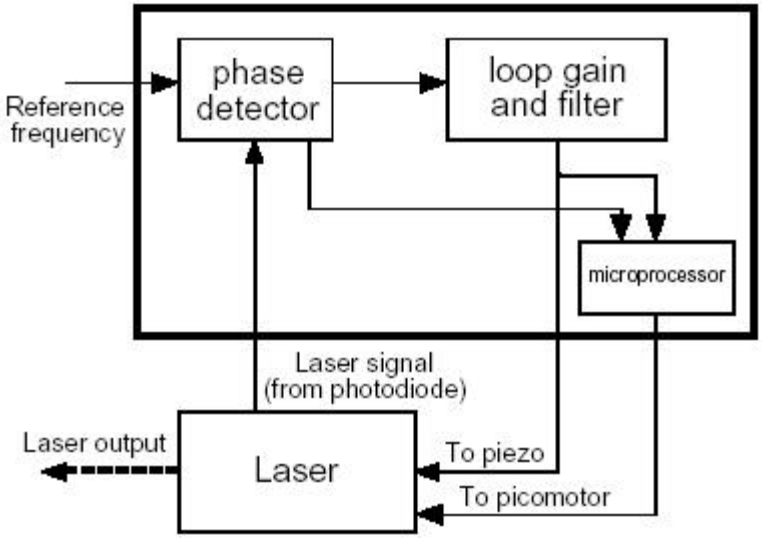
Repetition: 81.25 MHz

Pulsewidth: ~ 10 ps

Divergence: 1.5 mrad (full angle)

Timing stabilizer

- CLX-1100 Timing Stabilizer Feedback System
- Synchronizing laser to RF reference (phase-locked loop)
- Timing jitter < 1ps (rms)



E-beam parameters

- Energy: 1.5 MeV (35 MV/m @cathode)
- Current: ~ 0.2 mA (@1W laser)
- Bunch length: 10 ps
- Repetition: 81.25 MHz
- Transverse emittance: 0.6 π mm mrad /10pC
- Energy spread: 0.6% /10pC

Time line

Task	FY 2002			
	Q1	Q2	Q3	Q4
QE test	X			
Cavity polish and clean	X			
Cavity assemble and install		X		
Cavity low field test		X		
Cavity test			X	
Diagnostics design	X			
Vacuum and diagnostics install		X		
RF low test	X			
RF install and test		X		
Laser test and laser beam install		X		
Cryogenics design	X			
Cryogenics install and test		X		
Interlock and control		X		
Beam test			X	
Operation optimize				→

Thank you !