

Part I: Institutional Risk Assessment & Safety Protocols (Stages 1–3)

Hazard Category	Specific Risk Factor	Risk Level	Mitigation & Engineering Controls
Cryogenic & Thermal	Physical contact with liquid nitrogen (LN ₂) or ultra-cold surfaces (100 K) during Stage 1 and Stage 2 vitrification phases. Risk of severe cryogenic burns and localized frostbite.	Medium	• Mandatory PPE: Non-porous cryogenic gloves, full face shield, and closed-toe splash-proof footwear. • Automated micro-flow loops must be checked for line pressure limits before cooling cycles. • Vacuum-insulated transfer lines must be used exclusively.
Asphyxiation	Gas expansion and oxygen displacement due to slow or accidental LN ₂ boil-off within unventilated laboratory spaces.	Low	• Ambient oxygen depletion monitors with audible alarms must be active in the room. • Room ventilation must meet a minimum requirement of 10 air changes per hour (ACH).
Laser Radiation	Eye injury or retinal damage from exposure to Class 3B/4 continuous-wave lasers (532 nm green, 635 nm red) during single-molecule FRET alignment.	High	• Enclose the complete optical beam path using opaque, interlocked protective barriers. • Laser Safety Eyewear rated for OD5+ protection at the 532 nm and 635 nm wavelengths is required. • Place clear warning signage and active interlocks at the room entrance.
Mechanical / Acoustical	High-amplitude structural vibration from the electrodynamic modal shaker or high-decibel acoustic noise loops in the Stage 3 testing environment.	Low	• Enclose the Stage 3 modal shaker rig inside an acoustic isolation chamber to dampen ambient sound output. • Technicians must wear hearing protection (NRR 25+) when testing loops exceed 85 dBA.

Part II: Technical Data Collection Logs

1. Stage 1 Log: Single-Molecule FRET Data Acquisition Sheet

- **Experiment ID:** SMFRET-ST1-_____
- **Date:** ____/____/2026
- **Operator:** _____

- **Vitrification Temp:** _____ K
- **Piezo Transducer Output Power:** _____ mW

Frame Index (10ms)	Donor Count (I_D)	Acceptor Count (I_A)	Raw FRET Value (E_{raw})	Laser Intensity Baseline	Verification Notes / Artifact Check
00001					(Pre-Acoustic Baseline)
00100					(Pre-Acoustic Baseline)
00500					Acoustic Noise Loop Triggered
01000					
02500					
05000					
07500					
10000					End of Trace Loop
Post-Run Calculations: Mean E_{FRET} = _____ Standard Deviation (σ) = _____					

2. Stage 2 Log: Cryo-AFM Topographical and Phase Scan Template

- **Experiment ID:** AFM-ST2- _____
- **Date:** ____/____/2026
- **Operator:** _____
- **Cantilever Spring Constant (k_c):** _____ N/m
- **Actuator Resonance Target:** _____ kHz

Scan Line Index	Target Coordinate Zone (x, y)	Mapped Prime Index (p_n)	Peak-to-Peak Amplitude (nm)	Local Phase Shift ($\Delta\theta$)	Energy Trapping Indicator (Y/N)
Line 001	(,)	Anchor 2			
Line 050	(,)	Anchor 3			
Line 100	(,)	Anchor 5			
Line 150	(,)	Anchor 7			
Line 200	(,)	Intervening A-T			
Line 250	(,)	Anchor 11			
Line 512	(,)	Terminus Boundary			

3. Stage 3 Log: Macro Metamaterial Vibrometry Log

- **Experiment ID:** VIB-ST3- _____
- **Date:** ____/____/2026
- **Operator:** _____

- Rod Material Substrate: _____
- Shaker Input Profile: _____

Cell Index Position	Target Distance Metric (mm)	Local Mass Configuration (g)	Velocity Output (v_{out})	Input Force (F_{in})	Calculated FRF Value ($H(\omega)$)	Barrier Bandgap Attenuation (dB)
Cell 001	10 mm					(Input Anchor Reference)
Cell 002	20 mm	25g (Prime 2)				
Cell 003	30 mm	25g (Prime 3)				
Cell 004	40 mm	5g (Non-Prime)				
Cell 005	50 mm	25g (Prime 5)				
Cell 060	600 mm					(Midpoint Stress Matrix)
Cell 120	1200 mm					(Output Terminus)