

Periscope Telephoto Optics & SMA Actuators

Prism Optical Physics, Voice Coil Motor (VCM) Hysteresis, and Nitinol Phase-Transformation Mechanics

EXECUTIVE ARCHITECTURAL SUMMARY: Long focal-length smartphone cameras require folded periscope optics to fit 120mm equivalent focal lengths into 8mm device profiles. Moving heavy 250mg optical glass reflection prisms for sensor-shift Optical Image Stabilization (OIS) at high frequencies reveals fundamental limits in Voice Coil Motors (VCM), including electromagnetic antenna interference and coil Joule heating. Shape Memory Alloy (SMA) actuators utilize microscopic Nitinol wires undergoing martensitic crystal phase changes to deliver 100x higher force density with zero electromagnetic radiation.

Actuator Technology	Force-to-Weight Ratio	Response Time (OIS)	EM Interference (EMI)	Power at Hold State
Standard Voice Coil Motor (VCM)	1.0x (Baseline)	1.5 - 2.5 ms	High (Magnetic Coil)	Continuous Current
Ball-Bearing Suspension VCM	1.8x	1.2 - 1.8 ms	Moderate (Shielded)	Continuous Current
Piezoelectric Ultrasonic Motor	12.0x	0.8 - 1.2 ms	Low (Electrostatic)	Zero (Friction Lock)
Shape Memory Alloy (SMA Nitinol)	105.0x	0.5 - 1.0 ms	Zero (Non-Magnetic)	Low (Thermal Bias)

1. Optical Folding: Prism Physics in Sub-8mm Smartphone Profiles

Physical focal length is governed by the optical equation: $f = (H_{\text{sensor}} * D_{\text{object}}) / H_{\text{object}}$. A 5x optical telephoto lens (120mm equivalent) requires a physical lens barrel depth of approximately 14mm to 16mm, making planar perpendicular mounting impossible in an 8mm phone.

- Total Internal Reflection (TIR): A high-refractive-index right-angle glass prism reflects incoming light rays by 90 degrees, directing the optical path horizontally along the phone chassis.
- Aberration and Dispersion: Moving from single-axis lens shift to 3D prism-shift stabilization requires compensating for chromatic dispersion across the 45-degree angled glass interface.

2. The Voice Coil Motor (VCM) Bottleneck

Traditional camera autofocus and OIS modules utilize Voice Coil Motors consisting of copper coils suspended inside permanent neodymium magnetic fields (Lorentz force: $F = I * L \times B$).

- Coil Weight Penalty: To stabilize a heavy 250mg glass prism against hand tremors at 10,000 Hz, VCM coils must carry high currents (up to 300mA), dissipating substantial heat adjacent to the thermal-sensitive CMOS sensor.
- 5G RF Magnetic Cross-Coupling: Large permanent magnets in multi-camera modules distort radiation patterns of adjacent 5G millimeter-wave antenna arrays and trigger compass sensor errors.

3. Shape Memory Alloy (SMA) Solid-State Physics

Shape Memory Alloy actuators replace copper coils and magnets with ultra-fine wires (25um diameter) of Nickel-Titanium (Nitinol):

- **Martensite-to-Austenite Crystal Transition:** At room temperature, Nitinol exists in a twinned monoclinic crystal structure (Martensite). Passing a controlled electrical current pulse heats the wire past its transition temperature ($A_s \sim 70^\circ\text{C}$), collapsing it into a rigid cubic B2 lattice (Austenite).
- **Massive Contraction Force:** This microscopic phase change generates a contraction force exceeding 300 MPa, producing 100 times the force-to-weight ratio of a magnetic coil.
- **Zero Magnetic Signature:** Because SMA actuators contain no magnets or inductive coils, they emit zero electromagnetic interference (EMI), allowing camera modules to sit flush against 5G antennas.

4. Thermal Hysteresis & Sub-Micron Position Control

The engineering challenge of SMA actuators is thermal hysteresis: Nitinol contracts during heating at a different temperature than it expands during cooling.

- **Resistance Feedback Telemetry:** Modern camera controllers measure the dynamic electrical resistance (dR/dT) of the Nitinol wire in real time, calculating crystal phase state without external Hall effect sensors and achieving sub-micron optical positioning.

STRATEGIC ENGINEERING TAKEAWAYS & DEPLOYMENT RULES:

- Folded periscope optics utilize 90-degree total internal reflection prisms to achieve 120mm telephoto focal lengths in 8mm chassis.
- Shape Memory Alloy (Nitinol) actuators deliver 100x the force density of Voice Coil Motors with zero electromagnetic interference.
- Closed-loop resistance tracking overcomes Nitinol thermal hysteresis to achieve sub-micron optical image stabilization at 10kHz.