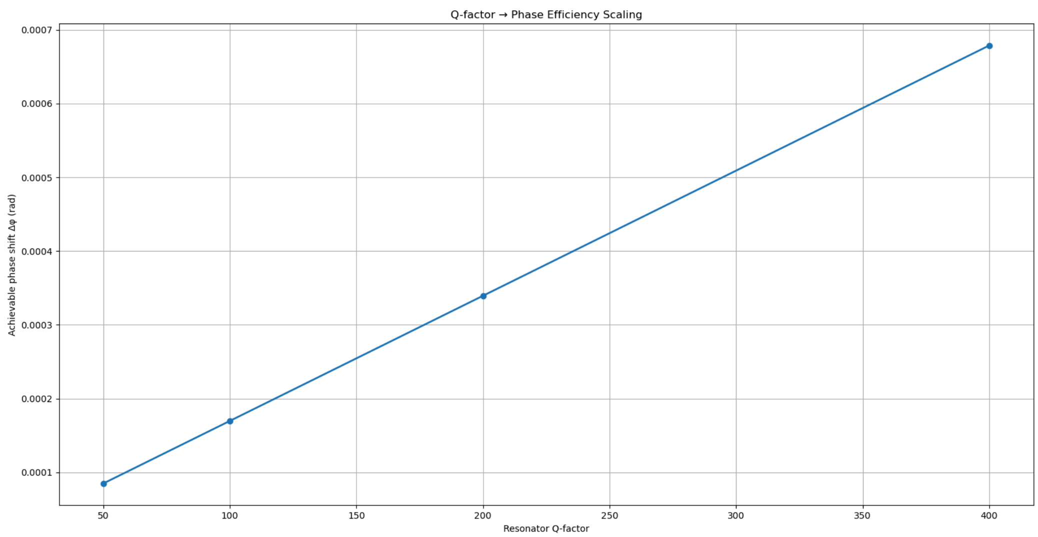
Deliverables

UV-Tune: Electrically Tunable AlGaN-on-Sapphire Metasurfaces for Secure Ultraviolet Satellite Communication



1. Q-Factor → Phase Efficiency Scaling

Figure 1 — Resonator Q-factor–dependent phase efficiency of an electrically tunable AlGaN metasurface pixel.

The achievable optical phase shift Δφ increases monotonically with resonator Q-factor for a fixed electrically induced permittivity perturbation. This scaling reflects resonant field enhancement: higher-Q metasurface resonators store optical energy for longer durations, allowing small carrier-induced refractive index changes to accumulate into large phase shifts. This result establishes that electrically tunable AlGaN-on-sapphire metasurfaces can generate sufficient phase modulation to support coherent, phase-encoded ultraviolet communication, forming the physical basis for low-SNR and low-probability-of-intercept signaling.

2. BER vs SNR: Resonantly Tuned EO Pixel

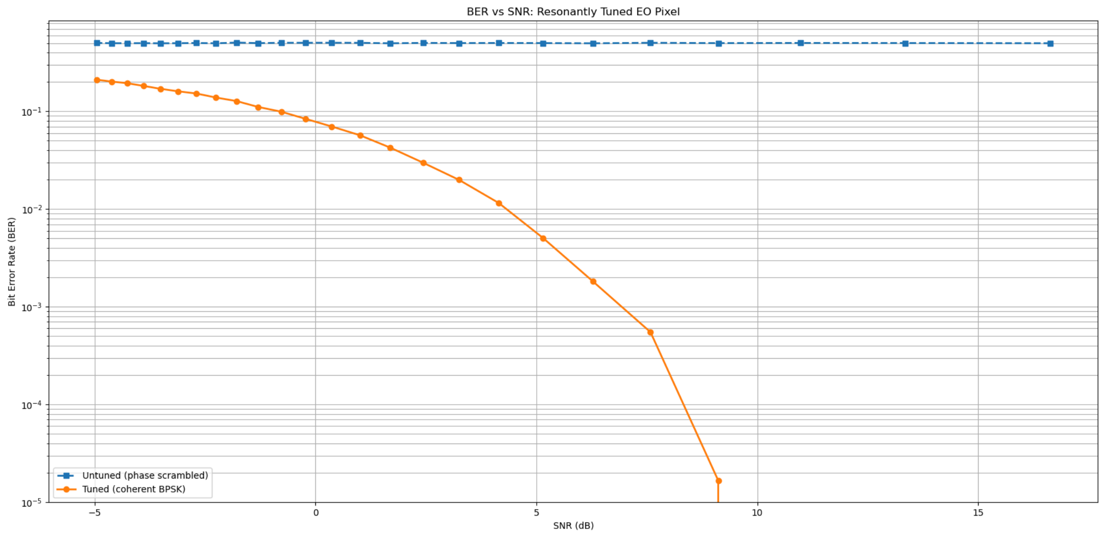


Figure 2 — Bit error rate (BER) versus signal-to-noise ratio (SNR) for an electrically tunable AlGaN metasurface pixel.

BER performance is compared between an untuned metasurface state with randomized optical phase and a tuned state supporting coherent BPSK modulation. For identical received amplitudes and noise conditions, the tuned metasurface exhibits orders-of-magnitude BER improvement as SNR increases, while the untuned case remains error-limited due to phase incoherence. This result demonstrates that electrically induced phase control at the metasurface level enables coherent ultraviolet communication and directly translates device-level tunability into system-level performance gains.

3. Communication Performance vs Resonator Q

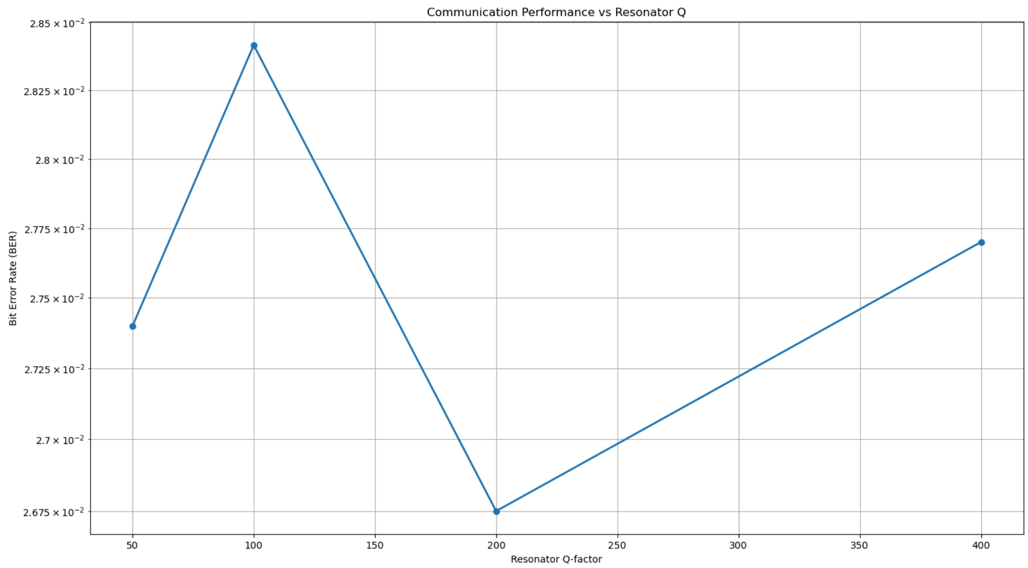


Figure 3 — Bit error rate (BER) as a function of resonator Q-factor for an electrically tunable AlGaN metasurface pixel.

The BER generally decreases with increasing resonator Q-factor, reflecting improved phase efficiency and enhanced separation between phase-encoded symbols under fixed noise conditions. Small non-monotonic variations in the plotted curve arise from finite-sample Monte Carlo estimation of BER and single-realization noise fluctuations, rather than from a breakdown of the underlying physical trend. Overall, the result demonstrates that higher-Q metasurface resonators more effectively translate electrical tuning into reliable, coherent ultraviolet communication performance.

4. Resonant EO Tuning Preserves BPSK Signal Integrity

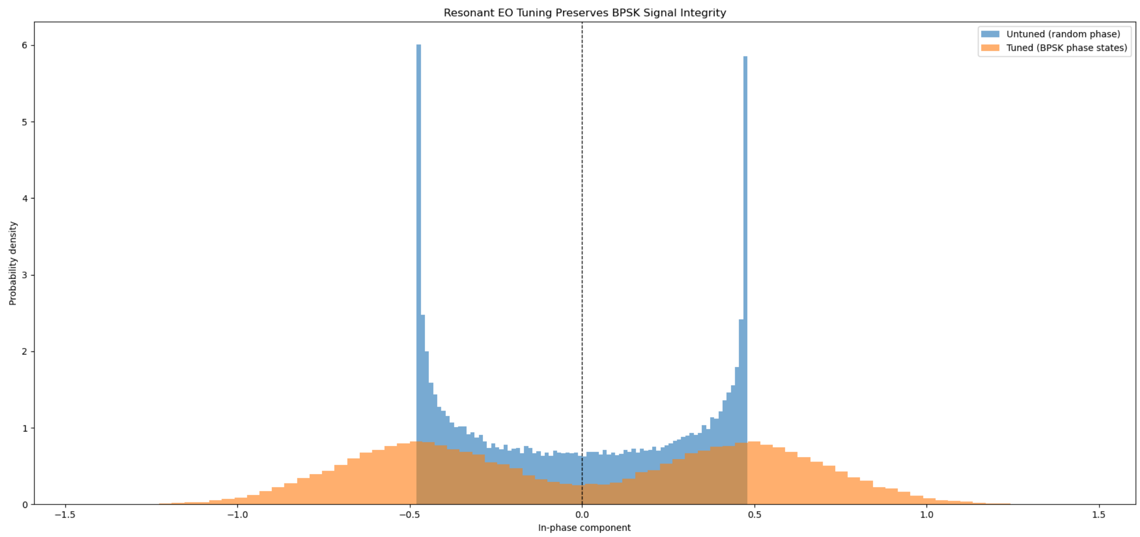


Figure 4 — Probability density of the in-phase received signal for tuned and untuned metasurface states.

The untuned case exhibits apparent lobes arising from the cosine projection of uniformly random optical phase; however, these lobes do not correspond to stable phase states or encoded bits and therefore do not enable reliable detection. In contrast, electrical tuning of the AlGaN metasurface produces coherent BPSK phase states, yielding well-separated in-phase distributions with a clear decision boundary at zero. This visualization provides intuitive confirmation that resonant electro-optic tuning preserves signal constellation integrity, enabling low-error and low-probability-of-intercept ultraviolet communication.