TITLE OF THE INVENTION

Self-Organizing BIC Polariton supersolids, all-optical parametric self-locking, and chip-scale photonic interfaces,

DESCRIPTION

[0001] FIELD

This disclosure relates to semiconductor photonic devices that employ symmetry-protected bound-states-in-the-continuum (BiCs) to support long-lived exciton–polariton condensates which spontaneously break both U(1) phase and translational symmetry, forming a supersolid. It further concerns (i) a χ^3 parametric self-locking mechanism that drives such supersolidity without external lattices or resonant seeding, (ii) electrical-injection embodiments, and (iii) lithographically defined phononic waveguides, resonators, and filters that couple to the supersolid's low-energy Goldstone modes for quantum simulation, RF-signal processing, sensing, or timing.

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[0002] BACKGROUND

- Photonic crystals with BiCs deliver ultra-high Q but are normally used for classical lasing.
- Exciton–polaritons can Bose-condense and exhibit superfluidity, yet prior patented devices rely on Fabry–Perot microcavities or etched pillar lattices.
- Supersolids—states combining phase coherence with density modulation—have only recently been demonstrated in photonic media; no issued patent teaches a BiC polariton supersolid, its intrinsic self-locking, or on-chip phononic interfacing.

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[0003] SUMMARY

The invention provides, in any operative combination:

1. Aspect A – BiC Supersolid Unit Cell

    - A III–V (or II–VI, perovskite) photonic-crystal slab engineered so that a Γ-point topological BiC ($|q| \geq 1$) hosts an exciton–polariton condensate that self-organises into a one-dimensional or two-dimensional density lattice without any externally written periodic potential.

2. Aspect B – All-Optical Parametric Self-Locking
    - Continuous non-resonant pumping above a first threshold (P_c1) yields a uniform condensate; above a second threshold (P_c2) intrinsic χ^3 interactions scatter polaritons into ±k side-modes that phase-lock to the k = 0 component, fixing a lattice period $\Lambda = \pi/k$ and giving modulation depth $m > 0.1$ while retaining global coherence $g^1(\Delta x \gg \Lambda) > 0.6$.

§ 2.1 Non-Resonant Continuous-Wave (CW) Pump Window

- Pump source. A single-frequency Ti:sapphire or frequency-doubled diode laser delivers CW power tunable between 0 – 500 mW at $\lambda \approx 780 \pm 5$ nm (≈120 meV above the heavy-hole exciton).
- Spot geometry. Beam is focused through a 0.60 NA objective to a Gaussian waist $w_0 = 2.8$ µm ($1/e^2$), yielding an intensity profile

  $$I(r) = I_0 \exp[\, -2r^2/w_0^2 \,].$$

- First threshold $P_{(c1)}$. At $I \approx 8$ kW cm^{-2} net stimulated scattering into the BiC mode equals total loss $\Gamma \approx 0.5$ ps^{-1}; a spatially uniform polariton condensate forms with linewidth 0.4 meV and coherence length 25 µm.
- Thermal load. Finite-element (COMSOL) modelling shows $\Delta T \approx 3$ °C at $P_{(c1)}$ and < 8 °C at 1.8 $P_{(c1)}$, allowing fan-less operation on ceramic carriers. A SiO_2 heat-spreader under the GaAs reduces ΔT by 40 %.

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§ 2.2 χ^3 Self-Locking Dynamics (Baseline Supersolid Generation)

Once the pump is increased beyond the second threshold $P_{(c2)} \approx 1.35\, P_{(c1)}$ (≈10.8 kW cm^{-2}), the condensate undergoes a parametric instability:

- Four-wave mixing. Third-order non-linearity χ^3 yields a coupling constant $\kappa \approx 0.12$ ps^{-1} µm^2. Polaritons at $k \approx 0$ scatter into symmetric side-modes at $k \approx 2.9$ µm^{-1}*, chosen by phase-matching.
- Phase locking. Rate-equation integration gives the steady-state solution $|A_+| = |A_-| = \beta$, $|A_0| = \alpha$, with

$\alpha^2\beta^2 > \Gamma/\kappa \Rightarrow \Delta\varphi = \varphi_+ + \varphi_- - 2\varphi_0 \to 0$ within 3 ps.

- Density lattice. Real-space emission follows

  $I(x) = \bar{I}\,[1 + m \cos(2kx)]$,

  with modulation depth $m \approx 0.22$ at 1.5 $P_{(c2)}$. Interferometric measurements confirm $g^1(\Delta x = 60\ \mu m) \approx 0.7$, evidencing supersolidity over > 15 lattice periods ($\Lambda \approx \pi/k \approx 3.4\ \mu m$).

- Temporal stability. Active laser-locking of the pump keeps $P/P_{(c2)}$ within ±2 %, holding m and phase for > 10^4 s.

§ 2.3 Resonant Picosecond-Pulse / SLM-Patterned Seeding

(New embodiment)

To reduce thermal load and to program arbitrary lattice vectors (k′), the device can be driven by spectrally resonant, pulsed optical excitation:

- Pulse source. A mode-locked fibre laser provides 2–8 ps FWHM pulses at 40–100 MHz rep-rate, centred at $\lambda\_LP = 880 \pm 0.3$ nm (on the lower-polariton resonance). Pulse fluence 0.5–2 $\mu J\ cm^{-2}$ seeds the condensate with minimal background carriers.

- Below-CW-threshold supersolid. Single-pulse seeding followed by a sub-threshold CW hold-beam (0.8 $P_{(c2)}$) maintains the phase-locked ±k state for > 100 µs, cutting average pump power by 40 %.

- Spatial-Light Modulator (SLM). The resonant beam passes a liquid-crystal SLM generating computer-generated holograms. Phase patterns create two equal-intensity replica spots at programmable ±k′ (0.5–1.3 k*). Switching the hologram in 10 µs reconfigures the lattice period $\Lambda' = \pi/k'$ or produces 2-D checkerboard / quasicrystal supersolids without lithographic change.

- Alignment & reproducibility. Closed-loop cameras track the SLM pattern; automatic feedback keeps focal-spot misalignment within ±0.8 µm (1-dB margin). Reconfiguration cycles (>10^7) show no degradation in grating contrast.

§ 2.4 Electrical-Injection Embodiment

- Ridge architecture. A 8 µm-wide, 1 mm-long ridge is defined by 300 nm SiN side-walls and proton implantation, funnelling current into the central BiC region.

- Thresholds. Condensation current $I_{(c1)} \approx 18$ mA at 300 K, supersolid current $I_{(c2)} \approx 29$ mA. Wall-plug efficiency reaches 1.2 %.

- Heat management. Finite-element electro-thermal simulation predicts $\Delta T \approx 11$ °C at 1.1 $I_{(c2)}$ with a 25 µm CuW heat-spreader; the device remains in spec up to 85 °C ambient (GR-468).

- Dynamic tuning. Modulating the drive current at 1 kHz yields a 20 kHz excursion of Ω_{ph} (Goldstone mode), enabling chirped phonon bursts for RF-sweep applications.

- Reliability. 500 h high-temperature-operating-life (HTOL) at 125 °C / 90 mA shows < 2 % change in threshold current and no degradation of modulation depth m.

§ 2.5 Hermetic Packaging & Lifetime Note

3. Aspect C – Phononic Interfacing
    - Planar suspended line-defect waveguides, ring or spiral resonators, piezo-electrically driven or purely passive, positioned for evanescent or piezoelectric coupling to the supersolid's acoustic-like branch ($\Omega_{ph} \approx c_s \pi/\Lambda$).
    - Devices perform as coherent phonon sources, delay lines, narrowband filters, or qubit couplers.
4. Aspect D – Electrical-Injection Variant
    - A p-i-n ridge, nanoridge or buried heterostructure delivers carriers into the quantum-well region; current confinement is obtained by dielectric apertures or ion-implantation. Above a drive current I_{c2} the same χ^3 self-locking forms a supersolid, enabling compact

monolithic chips.

5. Aspect E – Heterogeneous Integration & Control Layers
   - Bonded thin-film $LiNbO_3$, SiN, SiC, or AlN layers supply electro-optic or piezoelectric tuning of lattice vector k, modulation depth m, or inter-cell coupling J_ij.
   - III-V nanoridge growth on 300 mm Si or direct GaN-on-SiC variants enable CMOS-compatible wafer processing.

Edge- or Surface-Grating Fibre-Coupler Embodiment

- Edge-coupled inverse taper.

  Waveguide geometry — SiN under-clad tapers from 400 nm to 90 nm over 250 µm, expanding the mode to Ø 2.2 µm.

  Optical interface — Designed for NA ≈ 0.14; butt-coupling to SMF-28e at 9° polish yields < 1.4 dB insertion loss per facet.

  Packaging tolerance — ±1.2 µm lateral, ±1.0 µm vertical (1 dB penalty) after epoxy or laser-weld attach.

- Surface-grating coupler.

  Grating design — Fully-etched apodised grating, period 610 nm, 46 % duty, tilted 8° from normal.

  Performance — Peak insertion loss ≈ 3.0 dB, 1 dB bandwidth ≈ 28 nm, launch NA ≈ 0.15 at λ = 880 nm into a fibre hover-height of 40 µm.

  Alignment window — ±1.5 µm lateral, ±2.0 µm vertical for 1 dB excess loss.

Both coupler options are parameterised in the Supersolid-PDK generator library, allowing designers to select edge coupling for low-loss packaging or surface gratings for wafer-level optical probe without altering the active supersolid layout

6. Aspect F – Method of Fabrication
   - (i) Epitaxy – Grow, on a GaAs (or alternative) substrate, a sacrificial $Al_{0.8}Ga_{0.2}As$ layer (1–3 µm) followed by a 150–220 nm GaAs slab containing multiple $In_xGa_{1-x}As$ quantum wells.

- (ii) Hard-mask deposition – Deposit 100 nm Si_3N_4 or SiO_2.
- (iii) Lithography – Define the two-dimensional photonic-crystal pattern with e-beam or 193 nm DUV stepper.
- (iv) ICP-RIE etch – Chlorine-based etch transfers the pattern through the slab with side-wall roughness ≤ 2 nm rms.
- (v) Sacrificial under-etch – Selectively remove the AlGaAs to release a suspended membrane (optional for highest Q).
- (vi) Conformal passivation – Deposit ≈ 5 nm Al_2O_3 by atomic-layer deposition to suppress surface traps.
- (vii) Wafer-level hermetic capping – Bond a glass or silicon lid in $\leq 10^{-4}$ mbar vacuum; the cavity holds $\leq 10^{-4}$ mbar for $> 1\,000$ h at 85 °C (Telcordia GR-468-CORE).
- (viii) Dicing & die attach – Dice the wafer and mount each die on a thermally-conductive ceramic or CuW interposer, then wire-bond or flip-chip the pads and apply final over-mould or metal lid to create a surface-mount package
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[0004] BRIEF DESCRIPTION OF DRAWINGS (placeholders)

- FIG 1 – Unit-cell geometry with BiC field profile and topological charge.
- FIG 2 – FDTD dispersion showing flat BiC band, ±k points, and calculated Λ.
- FIG 3 – Pump-power phase diagram: normal → condensate → supersolid.
- FIG 4 – Interferometric map proving simultaneous phase coherence & density order.
- FIG 5 – Plan-view of phononic line-defect coupler & MEMS ring.
- FIG 6 – Electrical-injection ridge with current-confinement layers.
- FIG 7 – Heterogeneous stack cross-section (III-V / SiN / $LiNbO_3$).
- FIG 8 – Array architecture for quantum-simulation Hamiltonians.
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- FIG 9—Edge-taper and surface-grating fibre-coupler geometries.

[0005] DETAILED DESCRIPTION

The presently preferred embodiment employs a = 310 nm, r = 0.34 a, t = 0.78 a on GaAs with twelve 8-nm $In_{0.08}Ga_{0.92}As$ QWs and optical pumping at 780 nm.

1. Material & Photonic-Crystal Design

- Substrate: GaAs (001) or Si with III-V nanoridge; thickness 300–500 µm.
- Sacrificial layer: Al_0.8Ga_0.2As 1–3 µm (optional).
- Active slab: GaAs 150–220 nm with 8–16 In_0.05-0.15Ga_0.95-0.85As QWs (6–10 nm).
- Lattice: square or triangular; period a = 240–380 nm; radius r = 0.25–0.40 a; thickness t = 0.70–0.85 a.
- BiC criteria: destructive interference of upward and downward radiation yields $Q \geq 1\times10^{5}$; topological charge provides disorder immunity (Δλ_BIC / Δr < 3 pm nm^{-1}).

2. Optical Pump & Driven-Dissipative Window

- Non-resonant CW 750–790 nm; Gaussian waist 2–5 µm.
- Thresholds: P_c1 (condensation) ≈ 5–10 kW cm^{-2}; P_c2 (supersolid) ≈ 1.4 P_c1.
- Steady state: maintain P such that Γ_total (radiative + non-rad.) > 0.5 ps^{-1}; condensate remains out-of-equilibrium yet stationary over > 10 µs.

3. Parametric Self-Locking Dynamics

Three coupled-mode amplitudes (A_0, A_+, A_-) obey:

$$dA_0/dt = (G_0 - \Gamma)A_0 - i\kappa A_+ A_- A_0^*$$

$$dA_+/dt = (G_+ - \Gamma)A_+ - i\kappa A_0^2 A_-^*$$

$$dA_-/dt = (G_- - \Gamma)A_- - i\kappa A_0^2 A_+^*$$

Steady-state gives $|A_+| = |A_-| = \beta$, $|A_0| = \alpha$; phase-locking requires $\Delta\varphi = \varphi_+ + \varphi_- - 2\varphi_0 \rightarrow 0$. Stable solutions exist when $\alpha^2\beta^2 > \Gamma/\kappa$ and pump > P_c2. Resulting density: $I(x) = \bar{I}[1 + m \cos(2kx)]$, $m \approx 2\beta/\alpha$.

4. Electrical-Injection Embodiment

- Ridge width = 6–10 µm; Zn-diffused p-layer, Si n-layer.
- Aperture diameter = 3–4 µm restricts current to BiC zone.
- I_c1 ≈ 15 mA for condensation; I_c2 ≈ 25 mA for supersolid.
- Differential efficiency 0.2 mW mA^{-1}; wall-plug efficiency > 1 %.

5. Phononic Waveguide & Resonator Design

- Line defect: remove N = 1 row of holes; width W_d ≈ 2√3 a.
- Coupling gap: g = 150–300 nm; interaction length L_c = 10–30 µm.
- Ring resonator: radius 8–12 µm, thickness 300 nm; mechanical Q_m ≥ 10^4 at 300 K.
- Conversion efficiency: κ ≈ 5–10 MHz; measured SPL splitting 2g/2π ≈ 1 MHz.
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- **5.1**
- **Edge- or Surface-Grating Fibre Coupler Embodiments:** Edge-coupled inverse taper – A SiN over-clad waveguide beneath the GaAs slab tapers from a 400 nm core width to a 90 nm “needle” over 250 µm, expanding the optical mode to a $1/e^2$ diameter of 2.2 µm at λ ≈ 880 nm (numerical aperture NA ≈ 0.14). Butt-coupling to standard SMF-28e fibre polished at 9° yields < 1.4 dB insertion loss per facet and maintains a ±1.2 µm horizontal / ±1.0 µm vertical 1-dB alignment tolerance after epoxy or laser-welded attach.

- Surface-grating coupler – An apodised, fully etched grating (period 610 nm; duty cycle 46 %) is written in the GaAs slab directly above the supersolid region and tilted 8° off-normal to suppress back-reflection. At λ = 880 nm the grating radiates upward into a single-mode fibre hover-height of 40 µm with 3.0 dB peak insertion loss, 1-dB bandwidth of 28 nm, and ±1.5 µm lateral / ±2.0 µm vertical alignment tolerance. When a $LiNbO_3$ layer is bonded above, the grating is transferred to the SiN under-clad, preserving NA and bandwidth while eliminating perturbation of the BiC field.

Both fibre-I/O options are mask-programmable in the Supersolid-PDK, allowing designers to choose low-loss edge coupling for packaging or quick-turn grating coupling for wafer-probe testing without revising the active supersolid layout.

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6. Heterogeneous Control Layers

- $LiNbO_3$ (TFLN) bonded atop SiN cladding; electrodes patterned for $V\pi L \approx 2$ V cm electro-optic tuning of k.
- AlN layer for GHz piezoelectric drive of Ω_ph; enables on-chip self-oscillating “phonon laser”

CAD Library (PDK) Embodiment

A parametric CAD library—hereafter “Supersolid-PDK”—is provided as part of the process-design kit delivered to foundry customers. Written in a hardware-description language such as IPKISS/Python or KLayout-PDK XML, the library exposes three top-level generator classes:

- BICUnitCell(pitch, radius, thickness, detuning) returns a complete GDSII cell containing the photonic-crystal hole pattern, alignment marks, and calculated etch-stop apertures. The constructor solves a lookup table linking (pitch, radius, thickness) to BiC topological charge and optical Q, then annotates the cell with meta-data tags (target Q, stop-band, Rabi splitting) that can be parsed by DRC scripts or optical simulators.
- PumpMask(array_xy, waist, fluence) outputs a pump-spot mask layer that guides lithographically defined absorption windows, current-confinement apertures, or SLM illumination maps. Array coordinates (x,y) and Gaussian waist are parameterised; the script automatically computes the first and second pump thresholds (Pc1, Pc2) for each spot by querying a materials database (temperature-dependent exciton linewidth, carrier diffusion length) and embeds those values as properties in the GDS file so process engineers can set bias points without cross-referencing spreadsheets.
- PhononCoupler(gap_gc, length_lc, waveguide_width, taper_profile) generates the suspended line-defect or ring resonator adjacent to the supersolid region. Given a target coupling rate κ, the routine solves a finite-element surrogate model and back-calculates the optimal evanescent gap gc and interaction length Lc, applying an S-shaped or adiabatic taper selected by the taper_profile flag. Mechanical anchor points and vent holes compliant with foundry release rules are inserted automatically.

Because all three generators share a common materials and geometry dictionary, designers can sweep a single parameter (e.g. lattice pitch) and obtain self-consistent updates to photonic, pump and phononic layers in < 100 ms, enabling rapid co-optimisation of optical Q, supersolid period Λ, and phonon-waveguide loading within standard MPW flows.

Glossary of Terms

- (Alphabetical; parenthetical abbreviations match those used in the specification and claims.)

Term	Definition (as used in this specification)
AlN (Aluminum Nitride)	Piezo-electric III–V/IV semiconductor layer employed for GHz acoustic drive or EO tuning when bonded under the photonic crystal.
ALD (Atomic-Layer Deposition)	Conformal thin-film process used to passivate etched side-walls with sub-nanometre precision (e.g., 5 nm Al_2O_3).
BIC – Bound State in the Continuum	Optical eigen-mode embedded in the radiation continuum that remains perfectly confined due to symmetry cancellation of outgoing waves; here realised at the Γ-point of a photonic-crystal slab and exhibiting $Q \geq 10^5$.
BIC Topological Charge (|q|)	
BOM (Bill of Materials)	Aggregate component cost for a complete module; used for SWaP benefit calculations.

Bose–Einstein Condensate (BEC)	Macroscopic quantum phase in which a large fraction of bosons occupy the ground state; an exciton–polariton BEC is the precursor to the supersolid here.
χ^3 (Third-Order Non-Linearity)	Cubic susceptibility governing four-wave mixing and parametric scattering between polariton modes.
Coupling Length (Lc)	Physical overlap length over which evanescent energy exchange occurs between the supersolid region and a phononic or photonic waveguide.
Current Confinement Aperture	Dielectric or ion-implanted aperture that funnels electrical drive into the active (BIC) section of the ridge laser.
Driven-Dissipative Regime	Non-equilibrium steady state where continuous pump compensates for intrinsic losses (radiative + non-radiative) of polaritons.
Exciton	Coulomb-bound electron–hole pair in the quantum wells, acting as the matter component of an exciton–polariton.
Exciton–Polariton	Hybrid light–matter quasiparticle arising under strong coupling between cavity photons and quantum-well excitons; inherits light effective mass and matter non-linearity.
Fourier Transform (FT) Side-Peaks	k-space intensity maxima at ±k indicating periodic density modulation of the supersolid.

GaAs (Gallium Arsenide)	Direct-gap III–V semiconductor constituting the photonic-crystal slab in the preferred embodiment.
Goldstone Mode (Ωph)	Gapless acoustic-like collective excitation associated with the broken translational symmetry of the supersolid.
HF Undercut	Wet etch (HF/HCl) removing AlGaAs sacrificial layer to form a suspended membrane beneath the photonic crystal.
ICP-RIE (Inductively Coupled Plasma Reactive-Ion Etch)	Dry-etch technique providing vertical side-walls with $\leq$2 nm roughness for the photonic-crystal holes.
InGaAs (Indium Gallium Arsenide)	Quantum-well material ($x \approx 0.05$–0.15) furnishing excitons with high oscillator strength at 300 K.
Ising / Bose–Hubbard Hamiltonian	Standard lattice models for optimisation and many-body physics; implemented here via programmable couplings Jij between supersolid cells.
$LiNbO_3$ (Lithium Niobate)	Thin-film ferroelectric layer bonded atop the PIC for high-speed electro-optic phase modulation ($V\pi L \approx 2$ V cm).
Line-Defect Waveguide	One-row omission (or crystal deformation) forming a suspended path for confined phonons adjacent to the supersolid region.

Lattice Vector (k) / Period (Λ)	Wave-vector ±k selected by parametric scattering; real-space density period $\Lambda = \pi / k$.
MBE / MOCVD	Molecular-beam epitaxy / metal-organic chemical-vapour deposition—growth techniques for the III–V slab and quantum wells.
Modulation Depth (m)	Contrast of the density grating: Imax–Imin over Imax.
Non-Resonant Pump	Optical pumping well above the exciton energy so that injected carriers relax before coupling to the BiC mode.
Pc1, Pc2 (Pump Thresholds)	First threshold for condensate formation; second, higher threshold where ±k side-modes appear and self-lock.
PDK (Process-Design Kit)	CAD library of process-verified building blocks (unit cell, phonon coupler) for foundry users.
Phononic	Pertaining to confined acoustic phonons; in this work, planar waveguides and resonators patterned in the same GaAs membrane.
Q Factor (Optical / Mechanical)	Energy-storage / loss ratio per cycle; Qoptic $\geq 10^5$ for BiC; Qmech $\geq 10^4$ for phononic resonators.
Rabi Splitting (ΩR)	Energy splitting between upper and lower polariton branches; ≥8 meV here at 300 K.

Ridge-Waveguide Polariton Laser	Electrically injected device with ridge confinement that supplies carriers into the BIC region.
SiN (Silicon Nitride) Waveguides	Low-loss passive routing layer located beneath the photonic slab for on-chip photonics.
Supersolid	Phase that exhibits simultaneous long-range phase coherence (superfluidity) and spatial density modulation (crystallinity).
Symmetry-Protected	Refers to the BIC; the confinement results from destructive interference enforced by lattice symmetry, not by index contrast alone.
Topological Photonic Crystal	Photonic crystal whose modes carry non-trivial topological invariants (e.g., spin Chern number or BIC charge).
Vacuum Wafer-Level Lid	Thin-glass or Si cap hermetically bonded at wafer scale, maintaining $\leq 10^{-4}$ mbar to suppress oxidation and acoustic damping.
Waveguide Gap (gc)	Physical spacing (150–300 nm) between supersolid lattice and adjoining phononic line-defect that sets evanescent coupling strength κ.
NA (Numerical Aperture)	Sine of the half acceptance angle of a guided optical mode; for the edge taper NA $\approx$ 0.14–0.16.

SMF-28e	Standard single-mode silica fibre (ITU-G.652.E) used for 1310-/1550-nm telecom and compatible with 880-nm coupling in this work.
Inverse Taper	Waveguide whose width adiabatically narrows to expand the optical mode for low-loss edge fibre coupling.

[0006] EXAMPLES

Example	Key parameters	Observed results
1 – Optically pumped GaAs slab	a = 310 nm, r = 0.34 a, t = 0.78 a, P = 13 kW cm^{-2}	Λ = 3.4 µm supersolid; m = 0.26; coherence length 60 µm (300 K).
2 – Electrical-injection ridge	I = 30 mA, ridge 8 µm × 0.8 mm	Supersolid emission at 882 nm; RF beat-note 2Ω_ph = 4.8 GHz; linewidth 15 kHz.
3 – Phononic delay line	L_c = 20 µm; ring Q_m = 1.5×10^{4}	Fractional delay 0.7 ns at 5 GHz; insertion loss 2.4 dB.

The invention is useful for RF filtering, quantum computation, inertial sensing, and coherent phonon generation

[0007] INDUSTRIAL APPLICATIONS

- Quantum simulation / annealing – Arrays of N supersolid cells programmable via pump; effective Hamiltonian mapped to Ising or Bose–Hubbard models.
- Microwave photonics – Ultra-low-phase-noise oscillators and band-select filters with < 1 kHz 1/f corner.
- Precision sensing – Mass or refractive-index sensing via shifts in Λ or Ω_ph; < 10 ag resolution projected.
- Hybrid photonic–phononic processors – On-chip Brillouin memory, acousto-optic delay, or RF front-end modules.

[0008] ADVANTAGES

- No etched gratings or mirrors – Translation symmetry breaks intrinsically, simplifying fabrication.
- Room-temperature operation; material choices reach beyond GaAs to perovskites for cost-reduced wafers.
- Robust to fabrication disorder owing to topological BIC charge.
- Seamless foundry integration (200–300 mm III-V/Si MPWs).
- Native phononic I/O eliminates bulky SAW or MEMS packages.