Budget (lowest cost consistent with feasibility)

Section	Item	Qty	Est. Unit Cost (USD)	Subtotal	Notes
A. Vacuum & chamber	4–6″ CF/KF vacuum chamber (cube/tee)	1	900	900	Houses splitter, field-free cage, combiner, detector inside one rigid volume. The patent places these inside a vacuum housing. [Patent Images]
	CF/BK7 or fused-silica viewport (2.75″)	2	175	350	One for alignment, one for imaging.
	Electrical feedthroughs (BNC/SHV/multiconductor)	5	90	450	Biases for biprism, lenses, MCP, cage ground.
	Vacuum pumps (used bundle): rotary vane + small turbo (70–200 L/s) w/controller	1	2,800	2,800	Reach 10□□–10□^{7} Torr to preserve coherence. [Patent Images]
	Gauges: Pirani + cold-cathode/ion	1	550	550	Pressure readout rough □ high-vac.
	Valves, clamps, gaskets, plumbing	—	—	500	CF gaskets, KF clamps, bellows, tees.
A Subtotal				**5,550**	
B. Electron source (“beam generator”)	DIY thermionic gun (filament, Wehnelt, anode, ceramics)	1	300	300	Low-energy, compact; consistent with electron-beam embodiment. [Patent Images]
	Filament PSU (isolated low-V, 2–6 V/3 A)	1	120	120	
	Accelerator HV PSU (0–5 kV, few mA, low ripple)	1	850	850	

Section	Item	Qty	Est. Unit Cost (USD)	Subtotal	Notes
	Lens/Wehnelt bias (0–200 V)	2	140	280	
B Subtotal				**1,550**	
C. Splitter/combiner & electron optics	Electron biprism (etched W/quartz fiber + mount)	1	250	250	Low-cost, proven splitter/combiner approach.
	Electrostatic lenses/deflectors (rings/plates + standoffs)	set	250	250	Collimation/steering.
	UHV micro-positioners/mounts	set	350	350	Align splitter, cage, combiner.
C Subtotal				**850**	
D. Field-free cage & shielding	Copper or mu-metal tube (field-free cage)	1	80	80	Excludes external E/B fields; houses vector potential region. Patent Images
	Mu-metal sheets (external magnetic shielding)	2	160	320	Reduce ambient B-field noise.
	Small Helmholtz cancellation coils + current drivers	set	200	200	Trim residual fields.
D Subtotal				**600**	
E. Detector & readout	MCP + phosphor screen (2–3″, used)	1	950	950	Spatial fringes for direct visualization.
	MCP HV stack (2.5–3 kV)	1	350	350	
	C-mount USB camera + lens	1	220	220	Image fringes on screen.
E Subtotal				**1,520**	
F. Control, DAQ & mechanics	Multi-channel low-noise supplies/DACs (±0–200 V equiv.)	set	420	420	Scan biprism & lens biases; log response.
	USB DAQ (8–16-bit AI/AO) or MCU	1	250	250	

Section	Item	Qty	Est. Unit Cost (USD)	Subtotal	Notes
	interface				
	Small optical breadboard / isolation feet	1	320	320	Camera & external fixtures.
	Cables (BNC/SHV), interlocks, enclosures	—	—	220	HV safety + EMI cleanliness.
F Subtotal				**1,210**	
G. Consumables & metrology	Leak-check supplies, vacuum grease (KF), IPA/acetone	—	—	120	
	Basic HV probe / DMM (if needed)	1	180	180	
G Subtotal				**300**	

Project Total (practical minimum): ≈ $11,580
*(Absolute shoestring variant: swap MCP set for a CEM/Faraday cup + picoammeter (≈ $600–$1,000) and a smaller chamber to target **$8.5k–$9.5k**—but images of fringes are excellent for reviewers.)*

Technical Justification (≈2 pages)

Overview and mapping to the patent

US 8,389,948 ("Aharonov-Bohm Sensor") specifies an electron-beam interferometric device comprising a **beam generator**, **beam splitter**, **field-free cage**, **beam combiner**, a **vacuum housing**, and a **detector**. The first wave traverses the field-free cage and accrues a phase shift from the **vector potential** of a signal confined within the cage; the second wave serves as a reference. Recombination yields a modulated output beam detected downstream. Patent Images+1

Our bill of materials implements exactly those blocks:

- **Vacuum housing:** small CF/KF chamber with ports to mount the splitter, cage, combiner and detector in a rigid geometry. The patent describes first and second paths **disposed within a vacuum housing** to preserve coherence of both waves at **room temperature (≈15–25 °C)** and **without cryogenics**, provided scattering is minimized. Patent Images+1

- **Beam generator:** a compact thermionic source accelerates electrons to a few hundred eV–few keV into a low-divergence beam. The patent's electron-beam embodiment is compatible with low-energy paths as long as coherence is preserved. Patent Images
- **Beam splitter/combiner:** an **electron biprism** (charged fiber) is a low-cost, established element that both splits and later recombines matter waves by electrostatic deflection. The patent requires function (split/guide/recombine), not a specific part; a biprism satisfies "beam splitter" and "beam combiner" roles with simple DC control. Patent Images
- **Field-free cage:** a grounded, conductive tube around the first path that **excludes external EM, E, and B fields** while hosting the **vector potential** associated with the signal to be sensed. The patent states the cage excludes fields external to it so only the vector potential influences the phase. Patent Images
- **Detector:** an **MCP + phosphor + camera** provides high-gain, spatially resolved detection to visualize fringe modulation. The patent contemplates detecting a **modulated second electron beam** after recombination. Patent Images

Why a modest budget suffices

Short path lengths + high vacuum = room-temperature coherence. The patent explicitly notes that coherence can be preserved in vacuum between ~15 °C and 25 °C, avoiding cryogenics, if the two partial beams propagate in vacuum with negligible scattering. We target **10□□–10□^{7} Torr** with a used roughing pump + small turbomolecular pump bundle—common on the surplus market. This reduces the mean free path far beyond the **mm–cm** beam geometry, keeping dephasing low while keeping the footprint and cost down. Patent Images

Functionally minimal optics. A single biprism plus simple electrostatic plates/rings for collimation and steering minimize both parts count and controls. The biprism's bias provides a convenient **scan axis** for commissioning: as bias increases, you observe changing fringe spacing and visibility. That same control can be used to optimize interference before inserting the field-free cage. (The patent only requires the capability to split, route, and recombine; the biprism architecture is a frugal way to achieve that.) Patent Images

Detector choice tuned for reviewers. An MCP + phosphor + USB camera costs more than a single-channel CEM, but it provides **immediate, visible fringes**, letting a panel see phase-dependent modulation as a live image. Because the patent specifies detecting the **modulated second electron beam**, a 2-D imager is ideal for fast convergence and persuasive demonstrations. If the budget ceiling is firm, a CEM/Faraday cup + picoammeter can still measure **intensity modulation vs. phase bias**, though it sacrifices imagery. Patent Images

Risk and mitigation

- **Magnetic noise:** Ambient geomagnetic fluctuations and lab-nearby equipment fields can wash out visibility. We include **mu-metal shielding** and small **Helmholtz cancellation coils** driven by quiet current sources to trim static bias and suppress 50/60 Hz pickup—crucial for stable fringes in compact chambers. The patent's **field-free cage** already suppresses fields along the first path; external shields and coils protect both paths and the recombination region. Patent Images
- **Vacuum integrity:** Used hardware and careful cleaning (solvent rinse, new copper gaskets) plus a simple **leak-check routine** keep base pressure low. Our line items include fresh gaskets, valves, and gauges to de-risk commissioning.
- **HV safety & stability:** Separate supplies for filament, accelerator, MCP stack, and biases are itemized with proper **SHV/BNC cabling** and interlocks. Low-ripple supplies improve phase stability by reducing beam energy jitter.

Development milestones (aligned to claims)

1. **Vacuum commissioning (Weeks 1–3):** Assemble chamber, pumps, plumbing, and gauges; bake/light clean; achieve ≤10☐☐ Torr.
2. **Beam + imaging (Weeks 2–5):** Install gun and MCP; observe a focused spot and characterize stability.
3. **Interference (Weeks 4–7):** Install biprism and electrostatic plates; scan bias to obtain stable fringes; document visibility vs. pressure and lens settings. *(Maps to "beam splitter configured to split … and beam combiner … to generate a second electron beam.")* Patent Images
4. **Vector-potential sensing (Weeks 6–9):** Insert **field-free cage** over the first path; confirm that changing the **confined vector potential** (by adjusting the internal conductor current/geometry as allowed by the application) produces a **phase shift**—observed as a shift of the fringe pattern or a modulation in integrated intensity at fixed geometry. *(Maps to "phase of the first wave configured to shift in response to a vector potential … present within the field-free cage.")* Patent Images
5. **Characterization (Weeks 8–10):** Measure sensitivity (rad/√Hz), bandwidth limits (by bias scan rate and detector integration), and magnetic susceptibility (shields/coils on vs. off). Provide plots and images for the report.

Why this is credibly "minimum"

- Every block corresponds to a **specific requirement** in the patent; nothing extraneous is included.

- **Used/surplus** vacuum and detector parts dominate cost and are widely available; the rest is **DIY-friendly** (biprism, plates, mounts).
- The patent contemplates **room-temperature operation in vacuum** with short coherent paths—exactly what this budget delivers. Patent Images

Alternatives if you need to shave further

- Replace the MCP stack with a **CEM/Faraday cup** and a picoammeter (save ≈ $700–$900).
- Use a smaller KF-based chamber with one viewport (save ≈ $300–$500).
- Share a turbo/controller via a **gate valve** if your facility allows (save ≈ $1,000+).
  These bring the total close to **$9k** while maintaining technical plausibility.

If you want, I can also format this into a one-page budget sheet plus a two-page PDF brief with a cover and figure callouts from the patent for your submission packet.

Here's a pragmatic, **"lowest-cost but technically plausible"** bill of materials to prototype the AB sensor described in US-8,389,948 (Arman & Chase / Lockheed Martin). I'm assuming the patent's claims hold (e.g., room-temperature operation, short coherent paths inside vacuum, phase shift from vector potential inside a field-free cage) and optimizing for used/surplus gear where it makes sense. I also fold in basic safety and integration items you'll be expected to budget for.

Core references from the patent (what we must build)

The device needs (verbatim from the spec): a **beam generator**, **beam splitter**, **field-free cage**, **beam combiner**, **vacuum housing**, and a **detector**. The patent explicitly allows **room-temperature** operation with **coherence maintained** inside a vacuum enclosure, and suggests **compact path lengths** (order of mm–cm) to keep coherence without cryogenics. Patent Images+1

Itemized BOM (with frugal options)

A) Vacuum system & chamber (room-temp, compact)

1. **Vacuum chamber (small, CF/KF)**
    - Option: 6″ CF cube or 4–6″ tee with one viewport and 3–5 ports.
    - Rationale: Houses the splitter/combiner, field-free cage, short paths, and detector in one rigid volume. Patent places splitter, cage, combiner in a **vacuum housing** to preserve coherence. [Patent Images]
    - Est. cost (used/surplus): **$600–$1,200**
2. **Viewports (1–2×)**
    - 2.75″ CF fused silica or BK7, one toward detector/camera, one for alignment.
    - Est. cost: **$150–$300**
3. **Feedthroughs**
    - **SHV** (1–2×) for HV gun/anode/MCP, **BNC** (2–6×) for lenses/deflectors/biprism bias, **multiconductor** (for coils/sensors).
    - Est. cost: **$300–$600**
4. **Pumping set**
    - **Rotary vane roughing pump (4–8 CFM)** + **small turbomolecular pump (70–200 L/s) with controller**.
    - Goal: high-vacuum (10^{-6}–10^{-7} Torr) to keep mean free path Ạ path length.
    - Est. cost (used): **$2,000–$4,000** (bundle)
5. **Vacuum gauging**
    - **Pirani** (rough→mid) + **cold-cathode/ion gauge** (high-vac).
    - Est. cost (used): **$300–$800**
6. **Vacuum plumbing & hardware**
    - Clamps, CF copper gaskets, KF centering rings, valves, bellows.
    - Est. cost: **$400–$700**

Subtotal (A): ~$3,750–$7,600

B) Electron source (“beam generator 102”)

7. **Thermionic electron gun (low-energy) OR DIY filament/Wehnelt assembly**
    - Frugal path: DIY **tungsten filament + Wehnelt + anode** inside the chamber; adjustable 0.5–5 kV.
    - (Commercial miniature guns exist but are pricey; DIY is viable for proof-of-concept.)
    - Est. cost: **$150–$400** (mechanics, filament, ceramics, holders)
8. **Gun power supplies**
    - **Filament**: isolated low-V, high-current (e.g., 2–6 V @ 1–3 A).
    - **Anode/accelerator HV**: 0–5 kV, few mA (stable, low ripple).
    - Optional **Wehnelt/lens** bias: 0–200 V programmable.
    - Est. cost (used bench/HV modules): **$600–$1,200**

Subtotal (B): ~$750–$1,600

C) Beam splitter / combiner (electron biprism approach) & electron optics

9. **Electron biprism “beam splitter 106 / combiner 114”**
    - Classic low-cost approach: **charged nanowire/quartz fiber (gold-coated), sub-μm–few μm** as an electrostatic biprism to split and recombine matter waves (Tonomura-style). Electrostatic plates for steering.
    - You can DIY by electrochemically etching **tungsten wire** to sub-μm, mount in a rigid frame with fine adjusters.
    - Est. cost: **$100–$300** (wire, plating/consumables, micro-mount)
10. **Electrostatic lenses & deflectors (plates/rings)**

- 2–4 simple ring/plate elements (stainless or brass) on standoffs for collimation/steering; each needs a bias feedthrough.
- Est. cost: **$150–$400**

11. **Precision mounts & micrometers (inside chamber)**

- Small UHV-compatible posts/clamps OR custom PEEK/ceramic fixtures.
- Est. cost: **$200–$500**

Subtotal (C): ~$450–$1,200

D) Field-free cage (112)

12. **Field-free cage (Faraday shield tube)**

- Thin **copper or mu-metal tube** around the "first path," electrically bonded to ground via a dedicated feedthrough; slotted window if needed for physical layout. The patent calls it a **field-free cage** excluding external **EM/electric/magnetic fields** so only the vector potential couples. [Patent Images+1]
- Est. cost: **$40–$120**

13. **External magnetic shielding**

- 1–2 sheets of **mu-metal** around the chamber to reduce ambient B-fields.
- Est. cost: **$250–$500**

14. **Helmholtz cancellation coils (optional but helpful)**

- 2–3 coil sets to trim residual fields; low-noise current drivers.
- Est. cost: **$100–$250**

Subtotal (D): ~$390–$870

E) Detector (120) and readout

15. **Micro-channel plate (MCP) + phosphor screen**

- Standard, sensitive, 2–3″. Lets you see fringe modulation at the recombined beam.
- Est. cost (used/older models): **$700–$1,200**

16. **MCP HV supply stack**

- 2.5–3 kV stable, low-noise, with divider.
- Est. cost (used): **$250–$500**

17. **Imaging**

- C-mount CMOS/USB camera + lens focused on the phosphor screen; or a simple PMT/photodiode behind a slit for single-pixel fringe readout.
- Est. cost: **$120–$400**

(Alternate ultra-frugal detector path: channel electron multiplier (CEM) or Faraday cup + picoammeter. You lose spatial fringe info but can still track modulation vs. phase bias.)

- Est. alt.: **$600–$1,000**

Subtotal (E): ~$1,070–$2,100 (MCP route)
or ~$600–$1,000 (CEM/Faraday-cup route)

F) Controls, DAQ, and mechanics

18. **Low-noise DC supplies / DACs for biprism & lenses**

- Multi-channel ±0–200 V (or 0–100 V) with 1–10 mV resolution; can be bench PSUs + resistor ladders or an isolated DAC + HV op-amps.
- Est. cost: **$250–$600**

19. **USB DAQ** (8–16 bit, few analog I/O), or microcontroller plus USB interface

- For scanning biprism bias and logging detector intensity.
- Est. cost: **$120–$350**

20. **Optomechanics & isolation**

- Small **optical breadboard** / damping feet / sorbothane; posts and clamps outside the chamber for camera alignment.
- Est. cost: **$200–$600**

21. **Cabling, HV connectors (SHV), interlocks, enclosures**

- Essential for safety and stability.
- Est. cost: **$150–$300**

Subtotal (F): ~$720–$1,850

G) Build consumables & metrology

22. **Leak-check supplies** (isopropyl/acetone, vacuum grease for KF only, helium if you can borrow a sniffer)

- Est. cost: **$50–$150**

23. **Basic metrology** (DMM, HV probe, oscilloscope optional for ripple)

- Assume you already have lab basics; if not, add **$150–$400**.

Subtotal (G): ~$50–$550

Roll-up budgets (choose one)

- **Absolute shoestring (heavy used/DIY, CEM/Faraday-cup detector): $6.7k – $10.7k**
  (A low end vacuum set, DIY gun, DIY biprism, simple detector.)
- **Practical minimal (used pumps, MCP imaging): $8.9k – $14.2k**
  (Gives you spatial fringes so you can directly see phase-shift modulation.)
- **More comfortable margin (nicer chamber & supplies): $14k – $22k**

Why these are defensible: the patent explicitly places the **beam generator, splitter, field-free cage, combiner** in a **vacuum housing** to preserve coherence at **room temperature**, with **mm–cm** scale paths so coherence persists without cryogenics—this is exactly what the above spec targets. Patent Images

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Practical build notes (what reviewers will ask)

- **Vacuum & coherence:** The patent indicates coherence can be preserved **in vacuum at ~15–25 °C**, avoiding cryogenics, provided the two partial beams propagate **without scattering** and are recombined for phase comparison. Keep path lengths short and pressure ≤10☐☐ Torr to ensure mean free path Ạ geometry. Patent Images
- **One-electron regime:** The splitter is described as able to split a beam **one electron at a time** (superposition of two paths). For a frugal build, you can operate at very low current so that overlap at the recombiner stays in the single-electron interference regime (statistical fringes). Patent Images
- **Field-free cage (Faraday tube):** This is central to the claim—the **phase of the "first wave" shifts** due to **vector potential inside the cage** while **fields are excluded**; ground the cage, add external mu-metal and optional Helmholtz coils to suppress ambient B-fields. Patent Images
- **Beam splitter/combiner choice:** A **biprism** is the cheapest proven way to split/recombine electron matter waves with simple DC biases and micro-positioning. (The patent is agnostic about the exact element, only that it "splits" and later **combines** the waves and compares phases.) Patent Images
- **Detector choice:** An **MCP + phosphor + camera** is the most visual (funders love seeing fringes). If budget is extreme, a **CEM/Faraday cup + picoammeter** still lets you track **intensity modulation** vs. biprism

bias/phase but lacks spatial fringe images.

Deliverable framing for a small grant

- **Milestone 1 (4–6 weeks):** Vacuum system to 10☐☐ Torr; DIY electron gun produces stable beam on MCP screen.
- **Milestone 2:** Demonstrate **beam splitting** and **recombination** (fringes visible) by biasing biprism and deflectors.
- **Milestone 3:** Insert **field-free cage** around one path; show **phase modulation** of the recombined intensity when vector-potential conditions are varied (e.g., controlled current/geometry creating a confined A-field proxy).
- **Milestone 4:** Sensitivity characterization (SNR vs. integration time) and environmental robustness (magnetic shielding on/off).

These steps map directly onto the patent's block diagram: **beam generator ☐ beam splitter ☐ first path through field-free cage ☐ combiner ☐ detector** [Patent Images]

Funding Proposal generated by:

OpenAI. (2025). *Aharonov–Bohm Sensor: Budget & Technical Justification* [Technical proposal generated by GPT-5]. ChatGPT, GPT-5 model, OpenAI. Retrieved from https://chat.openai.com