

Emerging Trends in Photonics

A patent-landscape cartography of eight fast-growing domains

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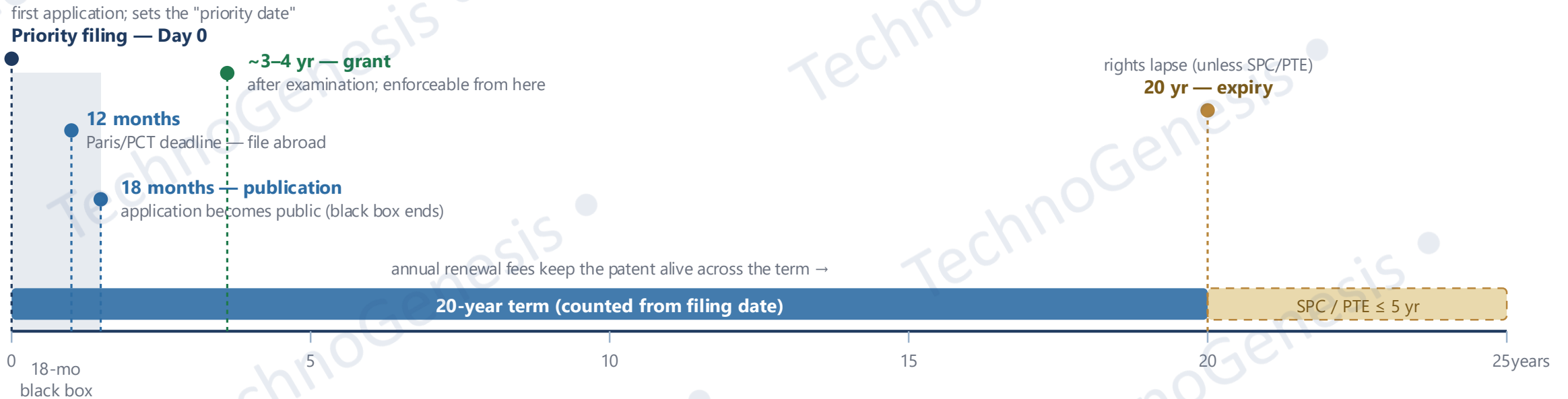
AGENDA

Numb	Domain	Studies/reports	Growth	Key IP players	Possible white spaces
I	Silicon Photonics & co-packaged optics	KnowMade/Yole	Very high	TSMC, Intel, Marvell, Huawei	AI-compute
II	Photonic Computing for AI	KnowMade/PatSnap	High	Lightmatter, Nvidia, IBM	Architecture-algorithm co-design
III	Quantum Photonics & Quantum Key Distribution (QKD)	EPO/Springer	High	IBM, Google, Origin, Toshiba	Chip-integrated QKD
IV	Metasurfaces & Flat optics	PatSnap/Optica	High	Metalenz/Harvard, Samsung	Consumer-scale manufacturing
V	Automotive LiDAR & Sensing	KnowMade	Very high	Hesai, RoboSense, Waymo	FMCW + Metasurface Steering
VI	Hollow-core fibre	Minesoft (TechnoGenesis)	Rising	Southampton/Lumenisity	Manufacturing & Cabling IP
VII	AR/VR waveguide displays	Market/publ.	High	Lumus, DigiLens, Snap, Microsoft	Single-layer metagrating
VIII	Biophotonics -> OCT & Wearable optical biosensing	Minesoft (TechnoGenesis)	Steady/high	Zeiss, Alcon, Canon, Topcon	OCT-guided robotics

Note: Figures preliminary and indicative –showing direction and relative scale.

The lifetime of a patent

From priority filing to expiry — and why priority year $\neq$ publication year



Priority year $\approx$ when the invention was made · Publication/grant lag 1.5–4+ years · Time runs from the filing date, not grant

THREE ROUTES TO PROTECTION

- **National** – file office by office (US-USPTO, CN-CNIPA, KR-KIPO).
- **Regional** –EPO (EP) ~ covers 39 states, (UP) ~ covers 18 states since 2024 .
- **International** – PCT (WO); one filing reserves entry to ~ 150 countries for 30/31 months before national entry-> **Is a route – no protection until national entry and grant!**

RIGHTS & PROTECTION

- **Territorial** -> protects only where granted
- **Claims define the legal scope** -> scope of a granted patent can never be broader than the application as filled.
- **publication** – when rights (i.e provisional protection) begins.
- **Grant** when enforceable protection begins.

PRIORITY YEAR = THE INVENTION MOMENT

- **Earliest priority year = when the invention was made**
- **Publication & Grant lag** 1.5-4+years; long procedure which can be longer in some jurisdictions (e.g. postpone examination in Germany up to 7 years)

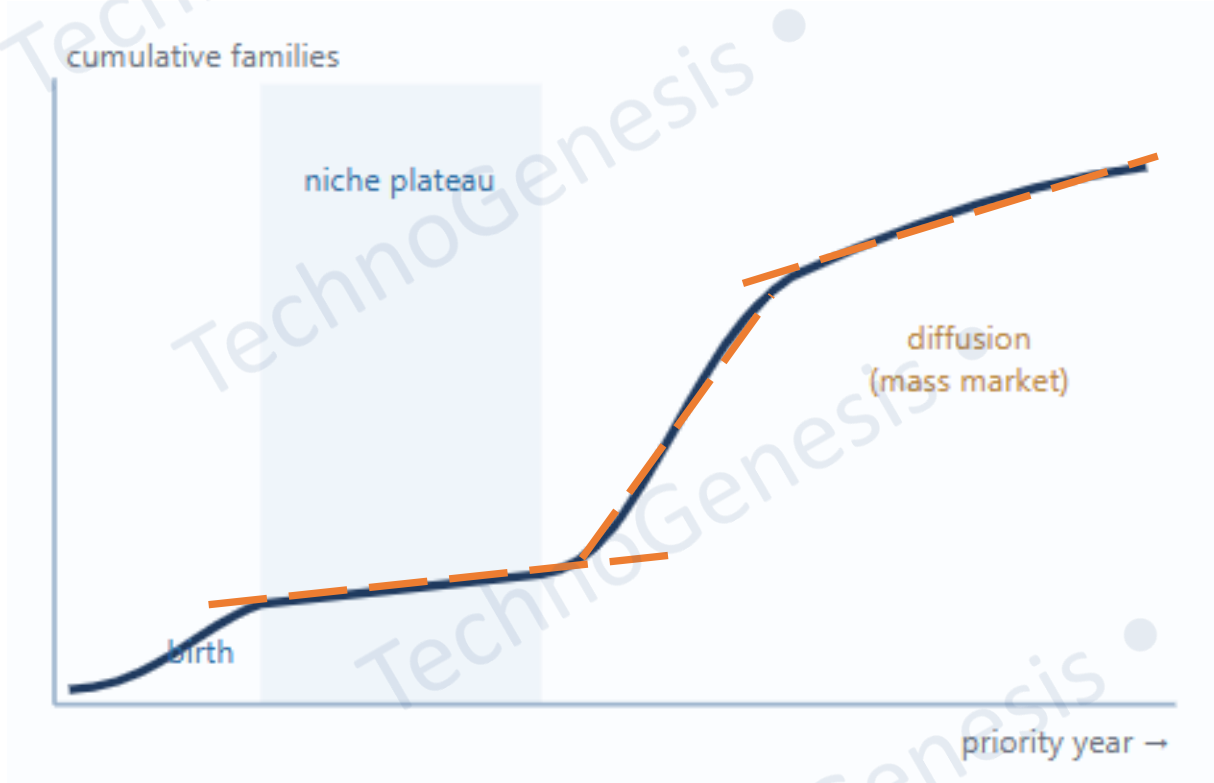
Methodology

- **Patent families analysis** – Family as a unit, plot versus priority year.
- **Combination of IPC/CPC classification codes** (Technology) & **Keywords** - (Title/Abstract/claims). Codes bound the domain, keywords refine them and catch emerging technologies that classification misses. (e.g. hollow –core: G02B 6/02328, OCT: A61B5/0066). One patent application can carry several codes

The 18-month black box & even more!

- **Black box**– Application stay secret ~18 months after earliest priority -> 18 last months can't be considered for an analysis
- **International routes** – EP and WO (30/31 months to know)
- **Volume ≠ value like publication ≠ grant**; counts differ by source & scope.

To take **away**– a count measures activity, not rights or value.



THE LOGISTIC S-CURVE

- **Emergence** -> steep adoption (invasion) -> **saturation** (consolidation)
- **Natural law of how technology spreads** (Bejan & Lorent, 2011)*

*Bejan, A. & Lorente, S. (2011), "The constructal law origin of the logistics S curve," *Journal of Applied Physics*, 110, 024901.

THE TRAP

- A long flat middle can be a **niche-restricted phase**, not maturity.
- Read too early, can't give safe conclusions.

An S-curve is a hypothesis about diffusion-not a verdict on maturity.

Hollow-core fibre

Studied in Minesoft Origin

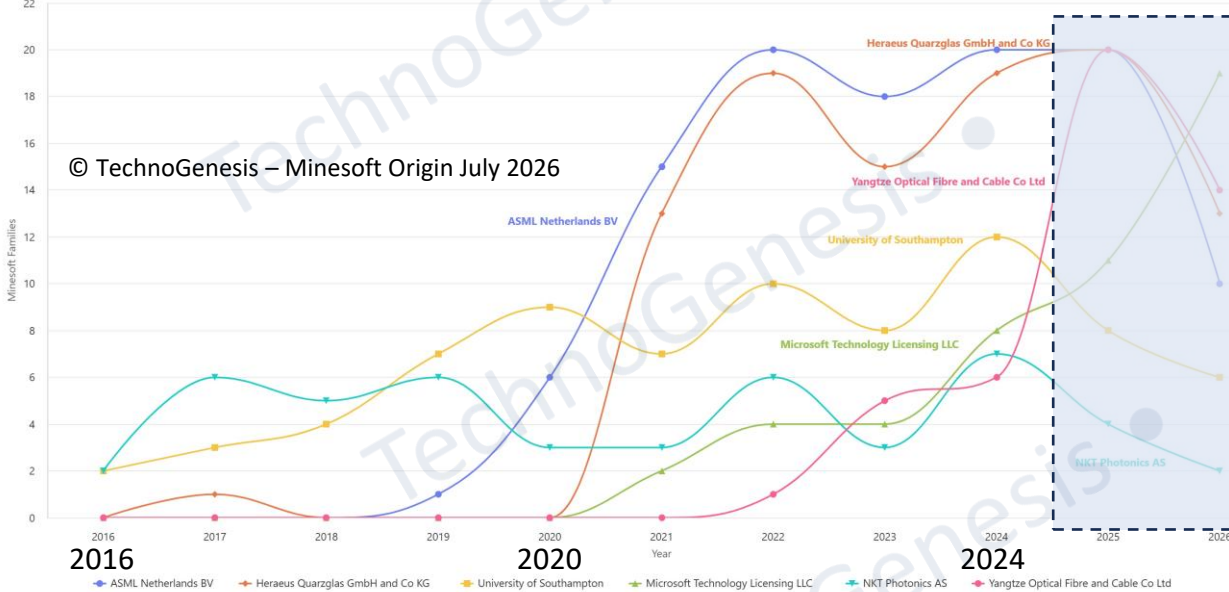
Number of priority application per priority year for the period 1994 to 2026

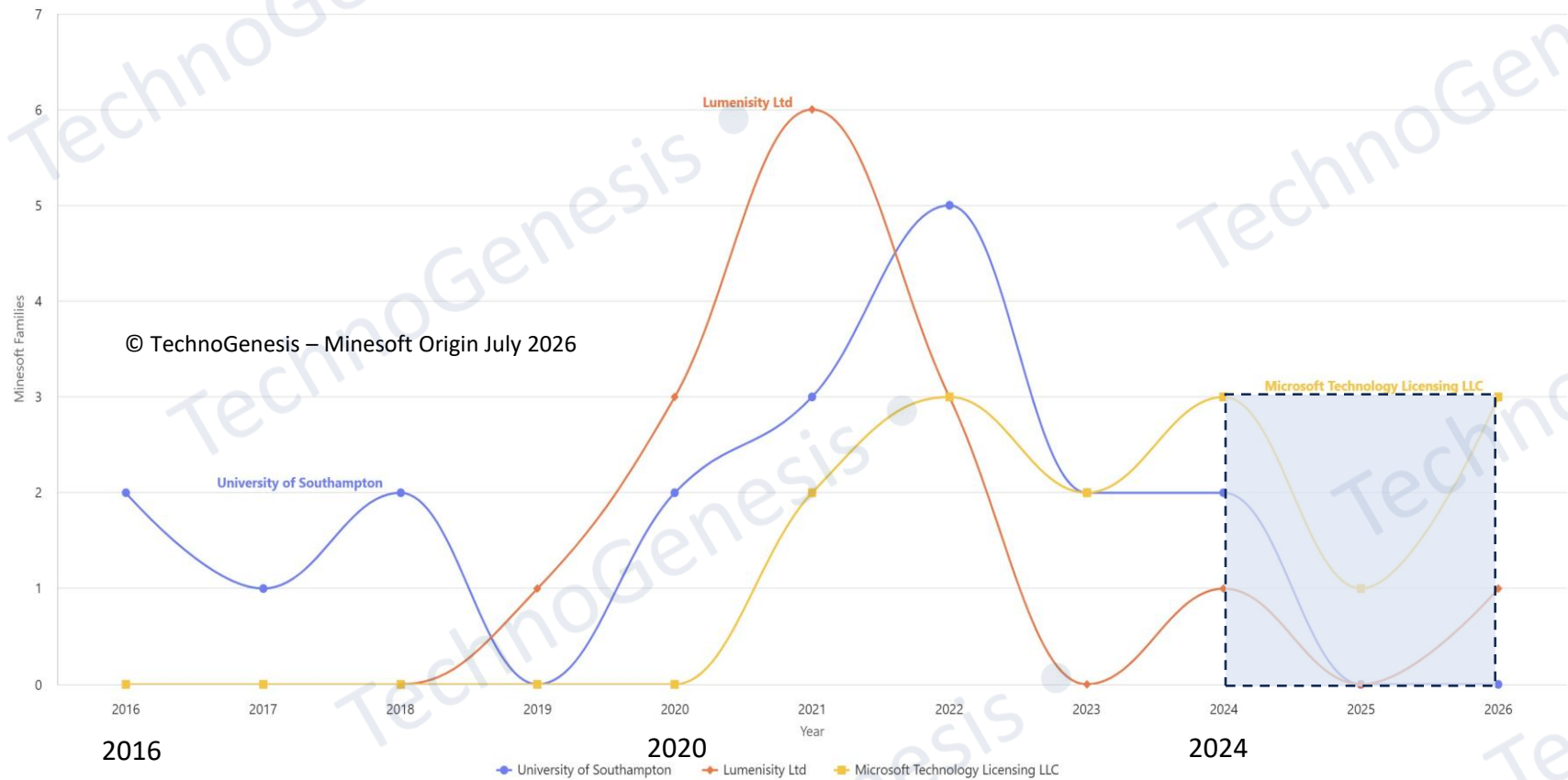


- **Not one S-curve but two waves:** – Family as a unit, plot versus priority year -> 2000-2004 (Photonic bandgap era), long plateau until 2013 (niche phase), 2014 pulled by AI data-centre latency.
- **No plateau reached until now:** – The domain is still open and white spaces remains (manufacturing, splicing and cabling process).

ASML: High-power beam delivery
Heraeus Quarzglas: Silica performer supplier
University of Southampton/Luminesity: Academic origin of NANF/DNANF
Microsoft Technology Licensing: Lumenisity acquisition
NKT Photonics: speciality Fibre
Yangtze Optical Fibre & Cable: China's entry

Top 6 Assignees for the period 2015 to 2026





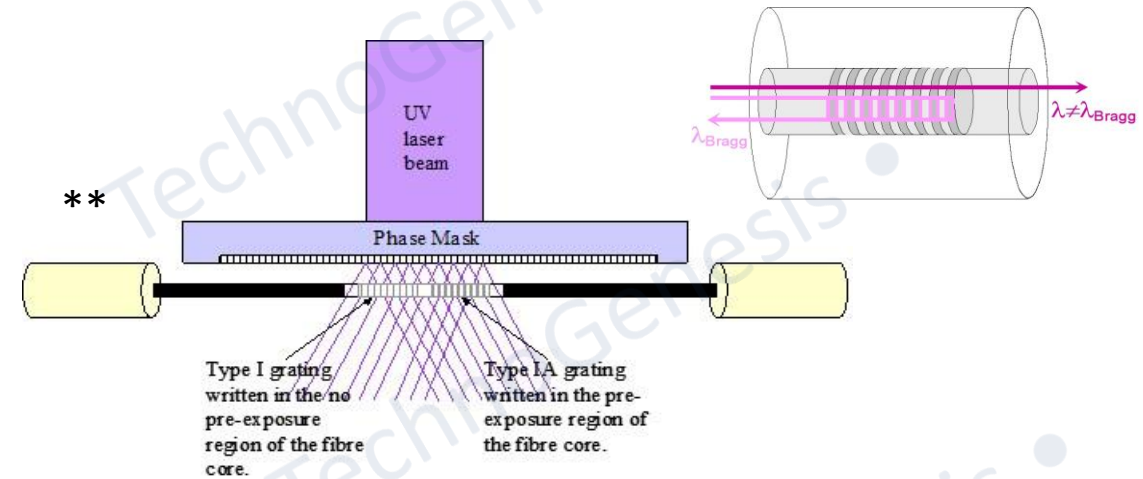
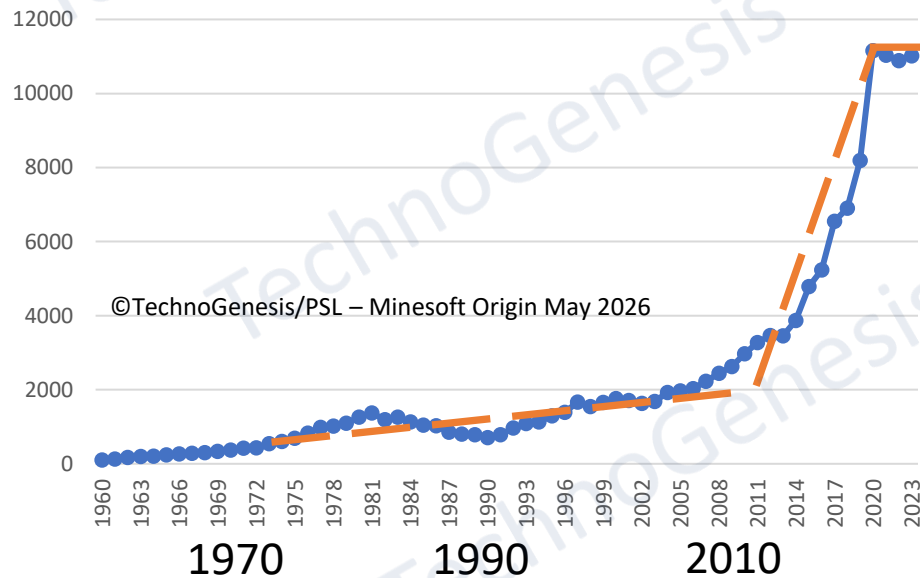
University of Southampton -> Spin out **Lumenisity** -> Acquired by **Microsoft** December 2022

A priority-year S-curve tells you **when** something was invented — not **when**, or **where**, it will matter.

Technology	Early restricted application	Later Growth & Diffusion
Aerospace insulation (Airbus)	Aircraft thermal control	Building envelopes *
Fibre Bragg Gratings	Motorsport (F1) & Aerospace measuring strain/temperature	SHM: bridges, dams, pipelines, wind turbines, medical equipment ***
Hollow-core fibre	High power delivery, gas sensing, gyroscopes	AI data-centre & HFT low-latency links
Adaptive optics	Military / astronomy (telescopes)	Ophthalmology, microscopy, free-space optics
LiDAR	Space / Military	Automotive & consumer

*(collaboration with PSL university, Paris, accepted for 16th Constructal Law Conf CLC2026)

Thermal insulation patent families per priority year from 1960 to 2024



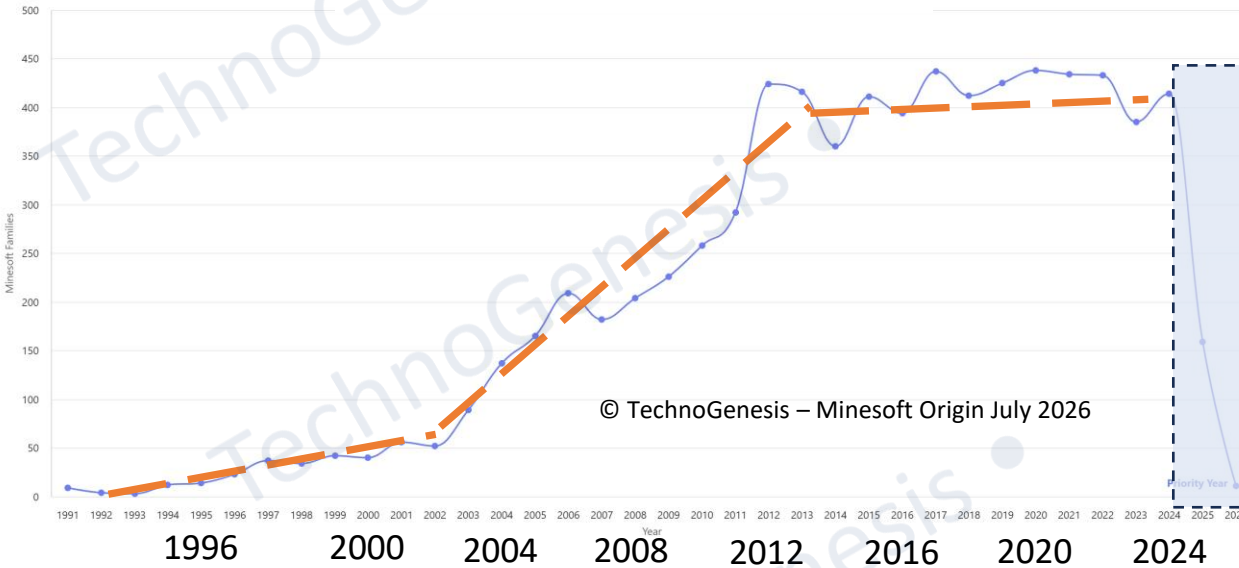
** Mexis, M. (2004). *Fiber Bragg Grating Sensing Systems*, MSc Thesis, Aston University.

*** Ren, H. (2020). *Flexible Robotics in Medicine: A Design Journey of Motion Generation Mechanisms and Biorobotic System Development*. Academic Press. <https://doi.org/10.1016/C2018-0-00607-6>

Biophotonics: Optical Coherence Tomography (OCT) & Wearable Optical Biosensing

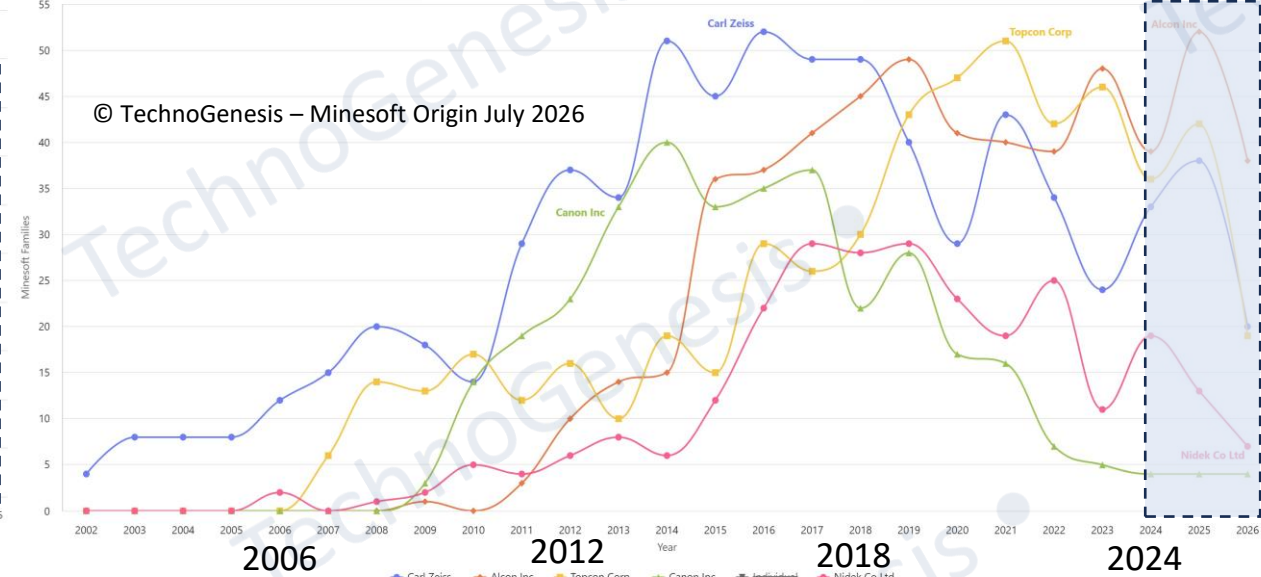
Studied in Minesoft Origin

Number of priority application per priority year for the period 1990 to 2026



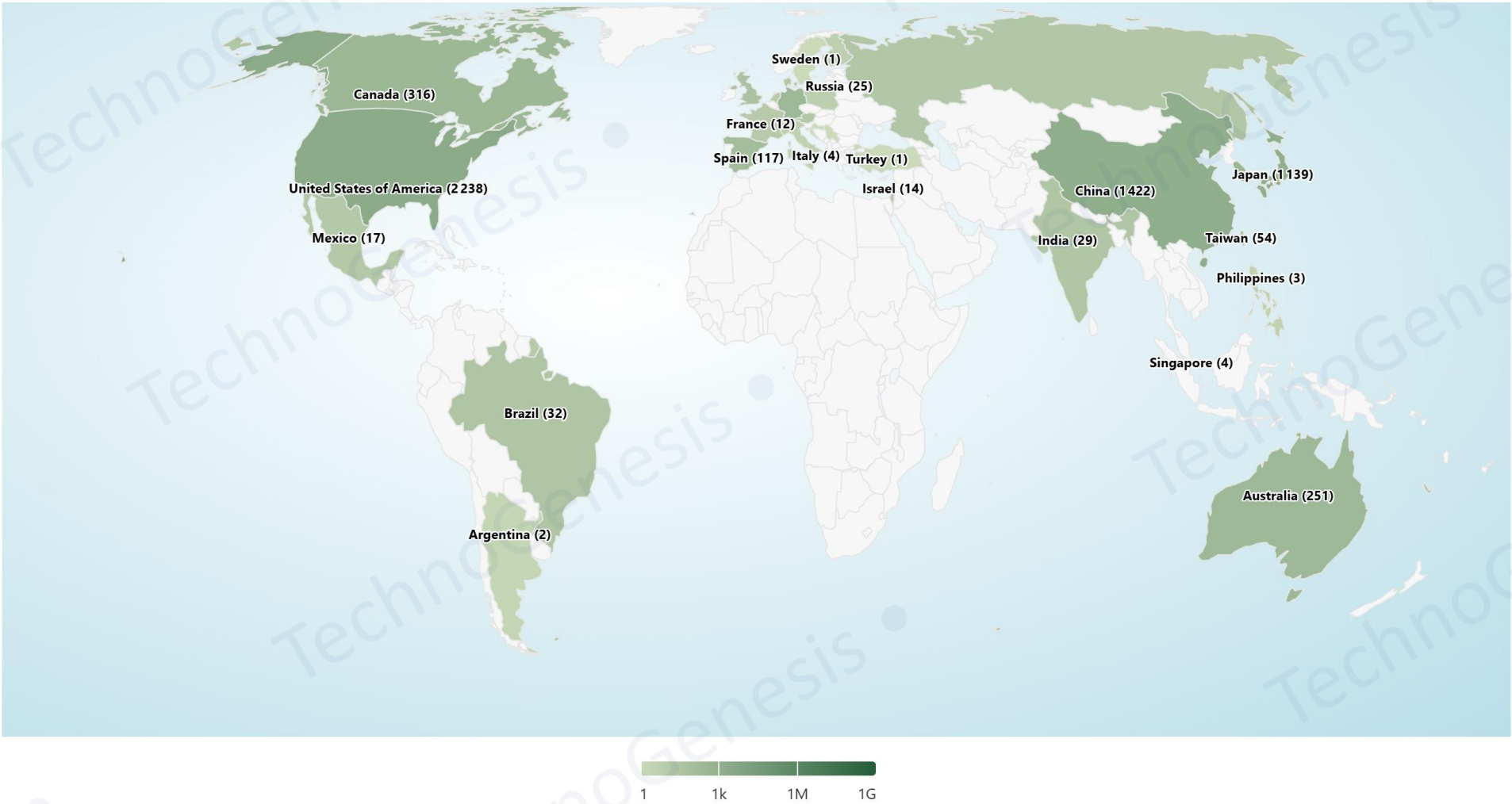
A **mature** domain: steep growth to ~2012, then a flat plateau of ~400 families/yr — saturation.

Top 5 Assignees for the period 2001 to 2026



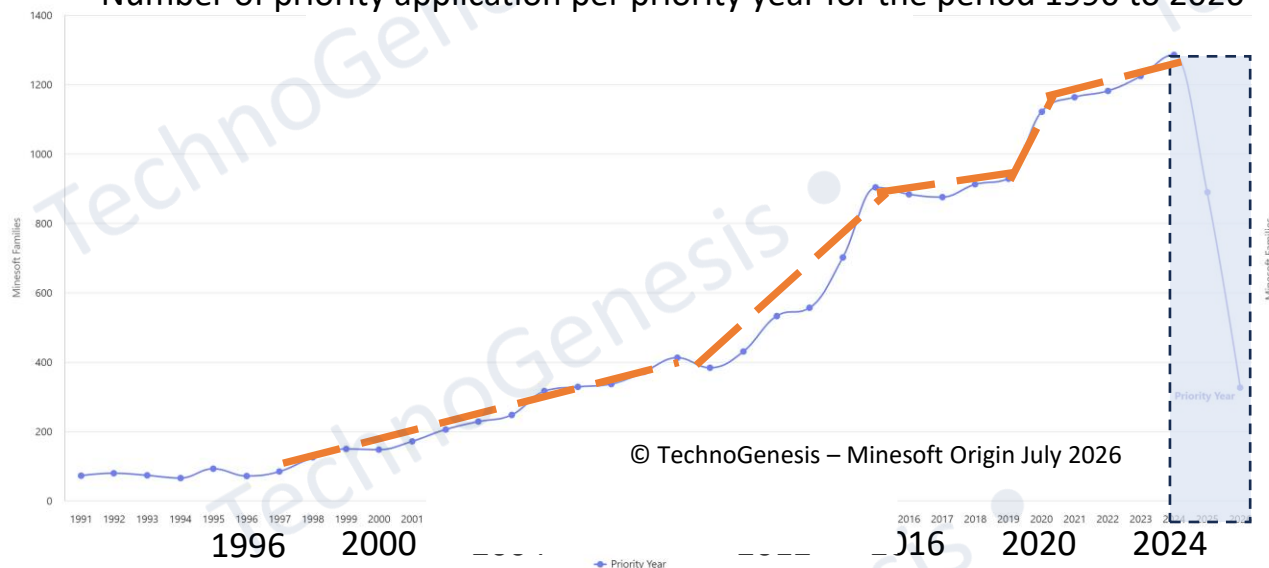
Carl Zeiss: Early & Sustained leader
Topcon & Alcon: Current front-runners
Canon: Optopol-driven wave (peak 2014, then retreat)
Nidek: Steady ophthalmic specialist.

Top 33 Jurisdictions by Minesoft Families



The US dominates, over the 2nd China by more than 60%, followed closely by 3rd Japan.

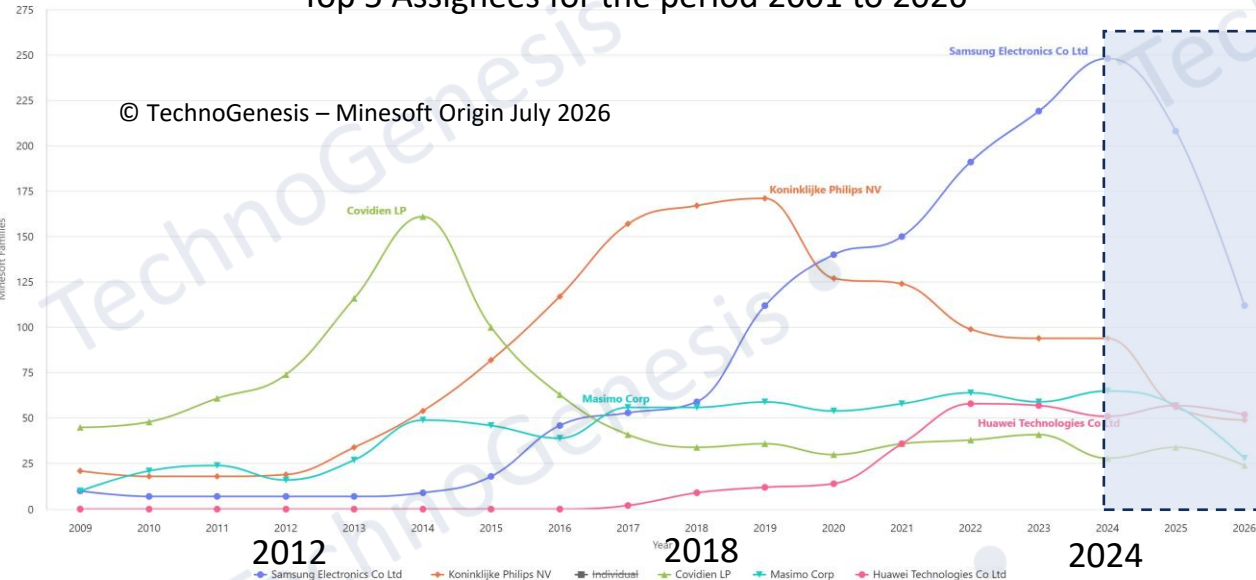
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Double S-curve: a first wave with the smartwatch / fitness-tracker (~2014–15), & then a second acceleration from 2020 (health monitoring) to a peak of ~1,285 families in 2024

Top 5 Assignees for the period 2001 to 2026

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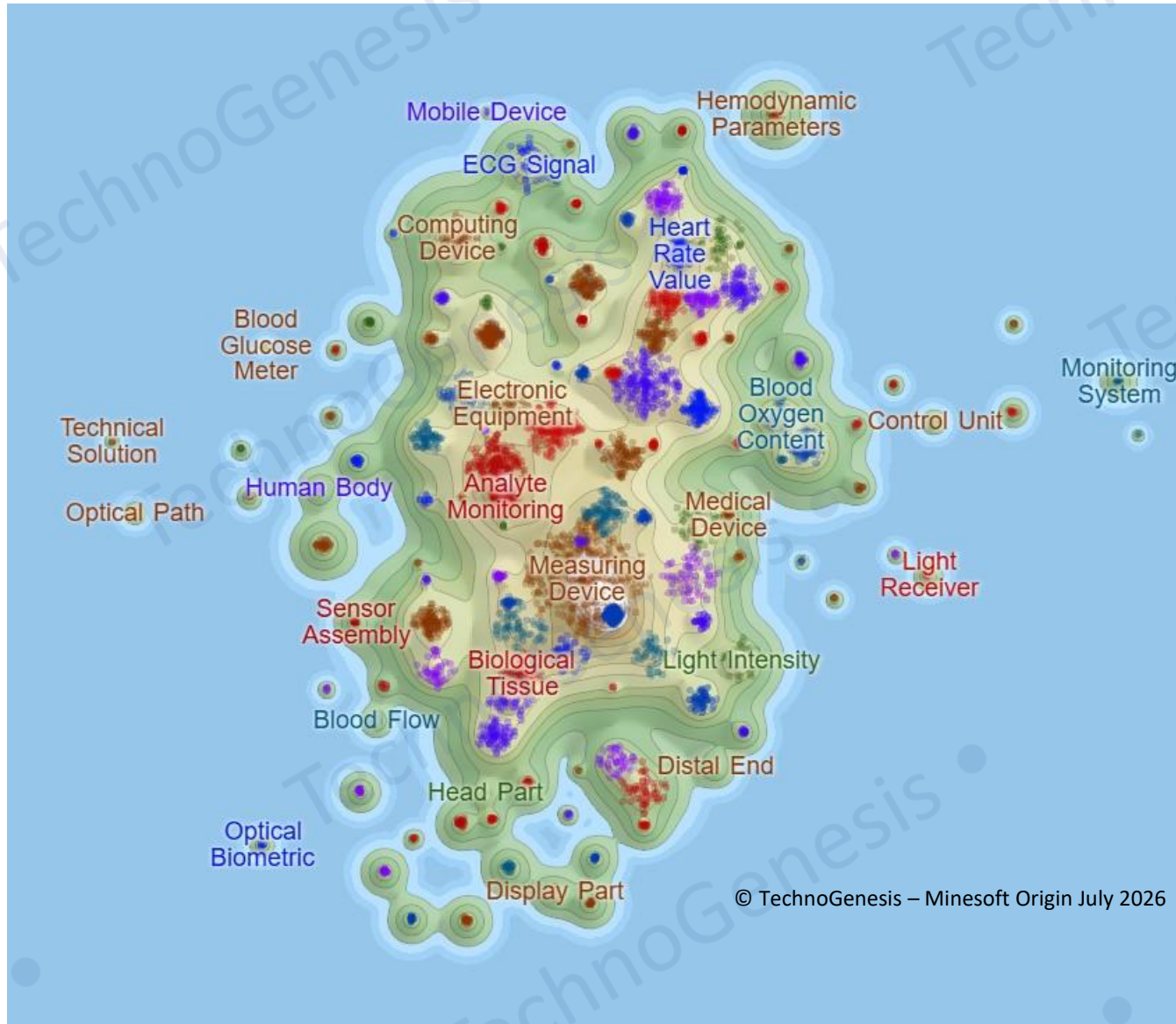
Samsung Electronics: Dominant and still rising to ~248 in 2024

Koninklijke Philips: peaked in 2019

Covidien LP: Early leader peaked in 2014

Masimo Corp: Pulse-oximetry pure player

Huawei: China entry in 2016



Fences (crowded, FTO risk) -> the vital-signs core — heart rate, ECG, blood-oxygen, hemodynamic parameters— plus the generic hardware massif (measuring device, sensor assembly, analyte monitoring)

White spaces (thin, at the edges): the optical-component periphery — optical path, light receiver, light intensity, optical biometric, blood flow — and the valleys between the consumer-device clusters (e.g. mobile/computing device, display part) and the clinical clusters.

Caution: empty doesn't mean valuable — a blank region can be infeasible rather than open.

Silicon photonics & co-packaged optics

Cited landscape

Figure	Value	Source (public)
CPO & optical-interconnect corpus	>4,000 patents/applications (2010–June 2025) → >1,300 patent families	Knowmade CPO Patent Landscape, press release 21 Jan 2026
Silicon photonics / PIC corpus (broader)	>13,300 families from >36,400 publications; ~1,700 families & 4,500 publications in 2025 alone	Knowmade Si Photonics & Photonic-IC dashboard, 2026
PIC filing growth	>30% CAGR since 2010	PatSnap / industry analyses
Leading assignees	Intel (flagged IP leader), TSMC expanding globally; Marvell, Broadcom, Huawei; plus emerging "newcomer" applicants	Knowmade press release & "Intel's IP leadership in CPO" article
Manufacturing direction	AI data centres pushing silicon photonics toward 300-mm wafer scale	Yole / Chiplet Marketplace, 2026
Market framing	Silicon photonics & CPO "at the heart of next-generation AI-driven data infrastructure"	Yole Group press release, 2025 (reports: <i>Silicon Photonics 2025</i> ; <i>CPO for Data Centers 2025</i>)

A very young corpus — **1,300 CPO families in five years** — sitting inside a 13,300-family silicon-photonicsbase growing >30%/yr.

A **packaging race**, where the whitespace is where photonics meets advanced packaging — chiplets and interposers — because very few players own both.

Shift to **300-mm wafers**: that is the signature of industrialisation.

Photonic computing for AI

Cited landscape

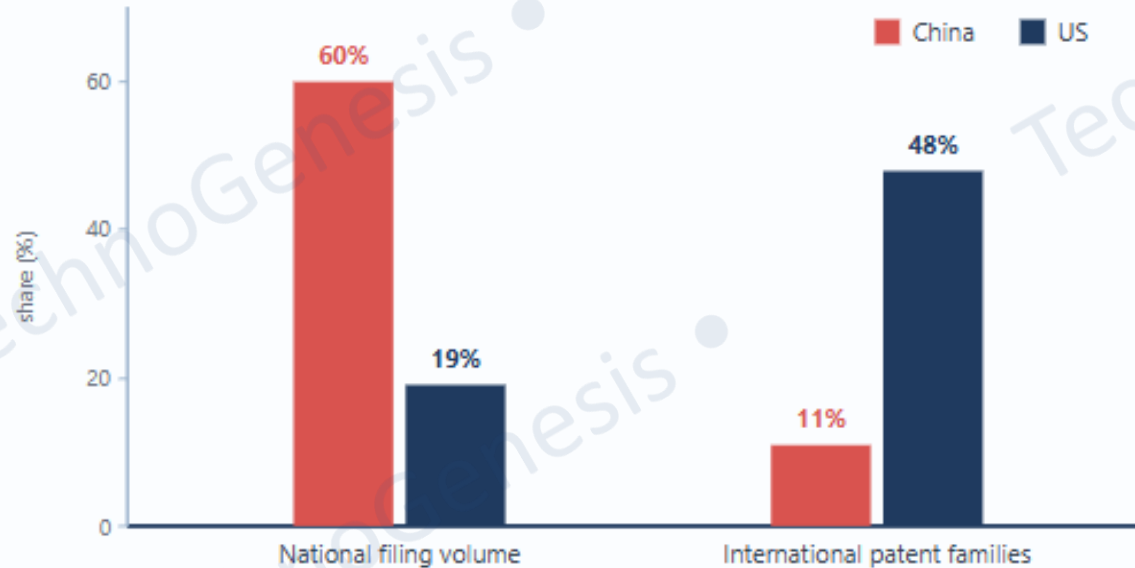
Figure	Value	Source (public)
Lightmatter patent portfolio	>60 patent families (Mar 2025); founded 2017	Knowmade, "Lightmatter's patent strategy" (2025)
Lightmatter funding / scale	\$400M Series D (Oct 2024); \$4.4B valuation ; ~\$850M total capital; Passage™ 3D-stacked photonic engine	Knowmade / company (2024–25)
Where it shows up in IP data	Lightmatter listed among key assignees (with Intel, TSMC, Huawei, Broadcom, Cisco) in the CPO / optical-interconnect landscape	Knowmade CPO Patent Landscape 2026
Active sub-fields	Photonic matrix multiplication and neuromorphic photonic computing flagged as growth areas	PatSnap landscape notes (2026)
Underlying PIC growth	Photonic-IC filings >30% CAGR since 2010; >1,700 families in 2025	Knowmade Si-Photonics dashboard; PatSnap

One pure-play anchor (Lightmatter, >60 families,) surrounded by incumbents filing around integration. Optical *interconnect* is the near-term commercial wedge; optical *compute* follows. Whitespace: **architecture–algorithm co-design** — foundational claims filed now could shape a decade.

Quantum photonics & QKD

Cited landscape

Figure	Value	Source (public)
Quantum-computing filing growth	~500 families (2011) → ~ 6,000 (2021) — nearly 12× in a decade	EPO Patent Insight Report, <i>Quantum Computing</i> (2023)
Quantum-tech grants per year	~500 (2004) → > 2,500 (2024) ; ~17.5% CAGR	Springer, <i>Mapping the Patent Landscape of Quantum Technologies</i> (2025)
Volume (national filings)	China ~ 60% of global (2024): 1,011 (2014) → 7,308 (2024); US ~19%	Springer (2025)
Quality (international families)	US ~ 48% , China ~ 11% — the inversion	Springer (2025)
Top assignees	IBM (191 grants, 2024), Google (168); Origin Quantum, Baidu, Tencent lead China; Toshiba & QuantumCTek in QKD systems	Springer / company press
Photonic slice	QKD is China-led; photonic <i>quantum computing</i> (PsiQuantum, Xanadu, Quandela) is Western	PatSnap photonic-QKD & photonic-QC landscapes (2026)



Volume East, quality West. Data: Springer (2025), *Mapping the Patent Landscape of Quantum Technologies*; EPO (2023). Chart recreated by the author.

China ~60% of national filings, the US ~48% of international families — volume East, quality West, in one inversion. Nearly **12× growth in a decade**.

QKD is China-led as a national-security priority, while photonic quantum computing (PsiQuantum, Xanadu, Quandela) is Western. For a European filer the lesson is explicit: compete on **defensible multi-jurisdiction families**, not on counts.

Whitespace: **chip-integrated QKD**

Metasurfaces & flat optics

Cited landscape

Figure	Value	Source (public)
Metalenx portfolio	>150 patents/applications, incl. >20 licensed from Harvard (Capasso lab)	Metalenx / Optica newsroom (2025)
First consumer metasurface	ST VL53L8 dToF sensor, June 2022	STMicroelectronics / Metalenx
Polar ID	~50% smaller & cheaper face-unlock; Samsung sensor (2024); UMC mass production (Nov 2025)	Optica / Metalenx
AR-metasurface leaders	Magic Leap, Microsoft, Samsung, Meta, Huawei, Metalenx, Shenzhen Metalenx	PatSnap AR-metasurface landscape (2026)
Convergence frontier	Single-layer full-colour metagrating AR waveguide	Nature Nanotechnology (2025)

Harvard's Capasso lab → Metalenx (exclusive licence, >150 patents) → ST, Samsung and UMC 2022.

In roughly four years it went from lab physics to a consumer product and then to massproduction.

That tells you where the whitespace has moved: **not the physics, but consumer-scale manufacturing and integration IP.**

Metasurfaces feed also the other domain LiDAR (beam steering) & AR (metagratings)

Automotive LiDAR & optical sensing

Cited landscape

Figure	Value	Source (public)
Landscape scale	> 36,000 patent families , >62,000 patents (Oct 2025)	Knowmade via Microwave Journal / Yole (2025)
Growth	Filings tripled since 2021 ; ~27% CAGR (2020–25); >24,300 families since Jul 2021	Knowmade press release (2025)
#1 patent holder	Hesai — 1st among LiDAR companies (holdings + strength); 3rd globally behind Bosch & Waymo ; 2,071 granted+pending (Nov 2025)	Knowmade / PR Newswire (Jan 2026)
Other key players	RoboSense, Ouster, Seyond, Aeva, Luminar, Innoviz, MicroVision, SiLC; Waymo & Opsys on architecture; Hyundai, GM as OEMs	Knowmade (2025)
Geography	China ~40% of publications by 2025	Knowmade (2025)
Hot growth areas	FMCW, metasurface beam steering, AI perception, multi-sensor fusion	Knowmade (2025)

IP crowded domain:
>**36,000 families**,
filings **tripled since 2021**.

Hesai is #1 among LiDAR pure-players, while Bosch and Waymo lead overall

AR/VR waveguide displays

Cited landscape

Figure	Value	Source (public)
Market leaders	Lumus + DigiLens ~28% combined share	AR-waveguide market analyses (2025)
#1 — Lumus (reflective)	~15% share; 6M+ AR devices shipped (2024)	market analyses (2024–25)
#2 — DigiLens (diffractive)	~13% share; 5M+ devices (2024)	market analyses (2024–25)
Other major filers	Snap / WaveOptics (15 new patents, 2025), Microsoft, Magic Leap, Samsung, Meta, Vuzix, Dispelix, LetinAR, Goertek	PatSnap / press (2025)
Convergence frontier	Single-layer full-colour metagrating waveguide (Samsung + POSTECH)	<i>Nature Nanotechnology</i> (2025), via Phys.org

Two leaders with **~28% combined share**: Reflective (Lumus) vs diffractive (DigiLens) vs the emerging metagrating.

Geographically, China leads volume, the US holds the architecture IP, Korea the manufacturing (Samsung wafer-scale), Europe the specialists. The frontier — **single-layer full-colour metagratings, SiC substrates, nanoimprint manufacturing** — is thin, and it is exactly where metasurface IP meets waveguide IP.

S-curves, white spaces studies

Methodology: Patent families by earliest priority year, bounded by IPC/CPC codes and refined with keywords.

Two domains studied in-house with Minesoft Origin (hollow-core fibre; OCT & wearable biosensing); six read from published landscapes.

S-curves place a technology on its diffusion path —emergence, invasion, saturation — and the **theme map** locates the fences and the white spaces. Limits kept in view throughout: the **18-month black box**, and **publication ≠ granted rights**.

Results: Three cross-cutting signals

China leads filing counts; the US and Europe still hold the international families.

AI is the tide. Co-packaged optics, photonic computing and hollow-core fibre are one story — the physical layer of AI compute.

The domains are converging. Metasurfaces feed LiDAR and AR; silicon photonics underpins quantum and computing. **Whitespace** is found at the interfaces.

Next

What this analysis does *not* yet tell us: legal status (are the fences still live?), claim-level scope, and citation quality.

The next layer is assignee harmonisation, legal-status filtering and claim-level whitespace mapping which can turn a landscape into a filing strategy.

Questions

Volume moved to China; quality stayed in the US & Europe —
and AI is pulling three photonics domains forward at once.

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