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I'll conduct deep research on the adoption of Co-Packaged Optics (CPO) in China's communications infrastructure, focusing on market outlook, investment opportunities, competitive landscape, supply chain risks, and technological advancements. I'll provide insights into key players, forecasts, and emerging trends based on recent data and expert analysis. I'll update you once the findings are ready.

Adoption of Co-Packaged Optics (CPO) in China's Communications Infrastructure

Co-Packaged Optics (CPO) is emerging as a key solution to overcome bandwidth and power limitations in data centers and networking equipment. By integrating optical components directly with switch ASICs, CPO can dramatically reduce electrical interconnect lengths and power consumption, enabling future network speeds beyond 800G and 1.6T. China, with its massive cloud and telecom infrastructure, is poised to both influence and benefit from CPO adoption – though the rollout will be gradual as the technology matures (花旗：CPO大报告.pdf). Below, we examine the market outlook, investment opportunities, competitive landscape, supply chain risks, and technological advancements shaping CPO's trajectory in China.

Market Outlook and Forecasts

The growth trajectory for co-packaged optics points to significant long-term impact, but a measured ramp in the near term. Industry analysts project that CPO will only represent a small fraction of network links mid-decade, then accelerate late in the decade. Citi analysts forecast CPO switch adoption reaching about **1% of 800G+ port shipments in 2026 and ~14% in 2027**, with a steeper ramp to **~30% penetration by 2028-2029** (花旗：CPO大报告.pdf) (花旗：CPO大报告.pdf). Similarly, LightCounting estimates **CPO ports will account for ~30% of all 800G–1.6T ports by 2027** (花旗：

CPO大报告.pdf). In absolute terms, Citi expects global CPO-enabled switch shipments to grow from only **~300 units in 2025 to 5,000 in 2026, then ~100,000 by 2027** as major cloud operators begin deployments (花旗：CPO大报告.pdf). This implies that 2025–2026 will see initial samples and trials, with volume adoption taking off in 2027 and beyond.

Forecasts for market size reflect this exponential growth. Research firm CIR projects the **CPO modules market to reach about $5.5 billion by 2027**, with data centers being the biggest driver (Co-packaged optics modules to be $5.5B market by 2027, says CIR | Lightwave) (Co-packaged optics modules to be $5.5B market by 2027, says CIR | Lightwave). Cumulative spending on CPO in data centers could hit $19 billion over 2023–2028 (Co-packaged optics modules to be $5.5B market by 2027, says CIR | Lightwave). By contrast, other analysts are more conservative – for example, Yole Développement reported the CPO market was only **$38 million in 2022** and may reach **$2.6 billion by 2033** (46% CAGR) (LPO vs CPO: Which Will Dominate the Data Center Optical Interconnect? | FS Community). This suggests limited deployments (mostly pilot projects) through the mid-2020s, then broader uptake in the 2030s. Industry consensus agrees that meaningful impact will be felt toward the **latter part of this decade**, as standards solidify and early implementations prove reliability. Even with surging data demand from AI and cloud, Dell'Oro Group cautions that **significant CPO volume is unlikely before 2027**, absent clear cost and power advantages to compel a faster switch from pluggable modules (Don't expect a lot of data switch CPO through 2027: Dell'Oro | Lightwave). In the long run, however, CPO is expected to become an inevitable part of high-speed networking as traditional copper and pluggable optics approach their limits (花旗：CPO大报告.pdf).

Investment Opportunities

The advent of CPO is creating both opportunities and risks for companies in the optical networking value chain. Key publicly traded players – especially in China – stand to benefit if they position themselves in the CPO supply chain, while others must adapt to avoid disruption. Below are some of the notable companies and startups to watch, along with potential earnings impacts and risks:

- **Chinese Optical Component Makers (Transceivers) – Innolight (SZ:300308)** and **Eoptolink (SZ:300502)** are leading Chinese suppliers of pluggable optical transceivers for data centers. Near term, these companies should see **continued demand for pluggable 400G/800G modules in parallel with initial CPO deployments** (花旗：CPO大报告.pdf). For instance, Citi forecasts transceiver volumes to grow alongside CPO through 2026 as CPO is only gradually adopted (花旗：CPO大报告.pdf). In the longer term, CPO could

cannibalize some pluggable module sales, so these firms are investing in CPO technology to stay relevant. Innolight has been at the forefront of past generational upgrades and is developing in-house CPO and optical engine capabilities (including supplying external laser modules) to maintain its edge (花旗：CPO大报告.pdf) (花旗：CPO大报告.pdf). A **risk** is that faster-than-expected CPO adoption or geopolitical restrictions could erode their market share at hyperscale cloud customers. For now, analysts see **no drastic near-term share loss** for Chinese transceiver vendors, but warn that slowed product cycles (due to CPO) and Western diversification efforts could pressure Chinese suppliers' growth over time (花旗：CPO大报告.pdf) (花旗：CPO大报告.pdf).

- **Chinese Optical Connectivity Suppliers – T&S Communications (SZ:300570)** and **Suzhou TFC Optical Communication (SZ:300394)** are two China-based companies poised to be big winners from CPO's new content requirements (花旗：CPO大报告.pdf). CPO architectures greatly increase the need for on-board optical connectors, fiber assemblies, and external laser coupling components, which aligns with these firms' specialties. T&S is a leading manufacturer of fiber optic connectors (MPO/MTP) and has developed **"fiber shuffle" assemblies** – an innovation for routing large numbers of fibers in CPO systems. Thanks to twin growth engines in its legacy MPO business and new fiber shuffle products, T&S is viewed as a prime beneficiary of CPO/Optical-IO adoption (花旗：CPO大报告.pdf). Analysts have raised estimates for T&S, seeing fiber shuffle demand as a major tailwind as CPO switch channel counts rise (花旗：CPO大报告.pdf). Meanwhile, TFC Optical is a specialist in optical engine packaging and connectors; it has been a **key supplier to Nvidia/Mellanox**, providing optical engine components and Fiber Array Units (FAUs) for AI interconnects (花旗：CPO大报告.pdf). TFC is expected to be the **primary supplier of FAU connectors and ELSFP (external laser ports) for Nvidia's first CPO switch systems** – positioning it for a surge in revenue as CPO devices enter production (花旗：CPO大报告.pdf) (花旗：CPO大报告.pdf). Both T&S and TFC have seen their stock targets upgraded on CPO prospects (花旗：CPO大报告.pdf). **Risks:** If CPO adoption is slower than anticipated or new competitors (domestic or foreign) enter the fray, these high expectations may not fully materialize. Additionally, the early CPO supply chain is concentrated – for example, **only a few firms (Japan's Senko, US's Corning, etc.) make certain connectors** (花旗：CPO大报告.pdf) – so any bottleneck or qualification delay at a key customer could impact these suppliers.

- **Global Network Equipment and Chip Makers** – Internationally, several tech giants are investing in CPO and could see upside. **Nvidia**, through its acquisition of Mellanox, has driven InfiniBand switch CPO development for AI clusters and is expected to launch sample CPO switches by 2025 (花旗：CPO大报告.pdf). While Nvidia's core business is selling AI systems, successful CPO adoption would strengthen its dominance in AI networking (potentially increasing demand for Nvidia's HGX systems and networking gear). **Broadcom** is another major player: it has code-named CPO switch projects (e.g. "Bailey") and is likely to introduce an Ethernet switch with co-packaged optics around 2026 (花旗：CPO大报告.pdf). If Broadcom can offer CPO-enabled switch ASICs with superior performance per watt, it could secure lucrative contracts with cloud providers – adding to the earnings of its switching silicon division. **Cisco Systems** has demonstrated a working CPO chassis and is researching co-packaged designs to maintain its hardware competitiveness (Cisco Demonstrates Co-packaged Optics (CPO) System at OFC 2023) (Cisco Demonstrates Co-packaged Optics (CPO) System at OFC 2023 - Cisco Blogs). Cisco, Broadcom, Intel, and IBM have all formed partnerships and industry consortia to advance CPO standards (Co-packaged Optics Market: Trends, Shares and Opportunities). For these large-cap firms, CPO is more of a strategic hedge; it could protect or expand market share in high-end switches. **Risks:** The **cost-benefit of CPO vs. improved pluggables (like Linear Pluggable Optics)** is still being evaluated by customers (Don't expect a lot of data switch CPO through 2027: Dell'Oro | Lightwave). If power savings or cost per bit fall short, cloud operators may delay CPO adoption, limiting the near-term revenue impact for suppliers. Additionally, these companies must navigate new manufacturing challenges (optical packaging), so execution will be key.
- **Startups and New Entrants** – A number of innovative startups are developing technologies that complement or enable CPO, making them potential targets for investment or acquisition. **Ayar Labs** (USA) focuses on optical I/O chiplets that enable optical communication between chips (often cited as Optical I/O, or OIO) – a technology that could be used for **optical GPU-to-GPU interconnects by 2027/28** in advanced AI systems (花旗：CPO大报告.pdf). Ayar Labs has partnerships with Intel and others, and if its in-package optical link technology succeeds, it could leapfrog into mainstream deployment for chip-to-chip connectivity. **Ranovus** (Canada) is another startup working on co-packaged optical engine solutions (it has demonstrated FPGA-based CPO modules and collaborates on standards). These startups and others (like consortium projects from Chinese research groups) stand to gain as larger vendors seek proven optical engine solutions. An **investment risk** here is that many startups will be

competing and not all will achieve scalable manufacturing; some may be acquired by bigger players for their IP. For Chinese investors, it's worth noting that **Chinese firms are also actively forming CPO alliances** – Chinese transceiver companies have a dedicated CPO development organization to drive the technology deeper into networks (Co-packaged optics modules to be $5.5B market by 2027, says CIR | Lightwave). This could spawn domestic startups or government-backed projects to reduce reliance on foreign optical components in the CPO era.

Competitive Landscape

The race to deliver co-packaged optics involves a mix of domestic Chinese companies and international players, each leveraging their strengths in optics, semiconductors, or systems. In China, the competitive landscape includes established optical manufacturers and newcomers adapting to CPO. **Innolight and Eoptolink** are the leading domestic module makers; both are developing CPO offerings to stay ahead, with Innolight using its strong R&D to prototype CPO transceivers and even seeking roles in providing optical engines or laser sources to U.S. cloud customers (花旗：CPO大报告.pdf). **Accelink, Hisense Broadband, and O-Net** are other Chinese companies to watch – for instance, **O-Net Technologies** was one of the earliest to demonstrate an ELSFP (External Laser Small Form-factor Pluggable) solution at an industry conference (花旗：CPO大报告.pdf). These firms are leveraging China's large ecosystem and government support to advance CPO research.

Internationally, **Broadcom and Nvidia** currently lead in developing CPO-enabled switch silicon. Nvidia's roadmap includes InfiniBand and Ethernet switches with co-packaged optics (expected to coincide with its "Spectrum X" and future "Rubin" architecture launches) (花旗：CPO大报告.pdf) (花旗：CPO大报告.pdf). Broadcom likewise is preparing CPO for Ethernet switching – both companies have the advantage of controlling the switch ASIC design, which is central to integrating optical engines. On the optical component side, traditional suppliers like **Lumentum, Coherent (II-VI), Sumitomo Electric, Senko, and Corning** are all involved in pieces of the CPO puzzle. For example, Corning (USA) provides fiber-optic interconnects and has been identified as a supplier of fiber shuffle assemblies for Nvidia's CPO systems (花旗：CPO大报告.pdf) (花旗：CPO大报告.pdf). Japan's Senko is known for its connector technology (e.g. SN-MT connectors) and is one of the few with expertise in the novel connector types CPO requires (花旗：CPO大报告.pdf). This means Chinese connector makers (T&S, TFC) compete globally with these incumbents.

In the realm of networking equipment, **Cisco, Arista Networks, and Huawei** are all monitoring CPO developments. Cisco has publicly demonstrated a CPO system and contributed to standards via the Optical Internetworking Forum (OIF). **Huawei**, while not publicly traded, is likely conducting in-house CPO R&D to enhance its data center switches – especially given China's desire for self-sufficiency in critical tech. **Arista** has so far focused on pluggables but could adopt CPO in future high-density switches, possibly sourcing technology from partners or startups. It's worth noting that co-packaged optics was initially seen as a strategy for U.S. firms to regain an edge, **mitigating competition from low-cost Chinese transceiver vendors** by shifting the paradigm (Co-packaged optics modules to be $5.5B market by 2027, says CIR | Lightwave). However, Chinese companies have responded quickly – by organizing industry alliances and accelerating their own CPO plans (Co-packaged optics modules to be $5.5B market by 2027, says CIR | Lightwave). This dynamic sets up a competitive race: whoever can deliver reliable, cost-effective CPO solutions first will shape the next-generation data center architectures. Collaborations are common – for instance, chipmakers are teaming with photonics specialists (e.g. **Intel with Ayar Labs, Marvell with OE vendors**) to share development costs. Standards bodies like the IEEE and OIF are also fostering an environment where multiple vendors' CPO components can interoperate (Co-packaged Optics Market: Trends, Shares and Opportunities), which will lower barriers for new entrants. In summary, the competitive landscape is both collaborative and competitive: a few tech giants driving initial CPO implementations, a cadre of specialized component suppliers (connectors, lasers, photonic chips) vying for design wins, and Chinese and international consortia ensuring that no single region or company monopolizes the technology.

Supply Chain Risks

Implementing co-packaged optics at scale presents several supply chain and geopolitical challenges. Because CPO is a nascent technology, **many of its components are new or not yet proven in high-volume manufacturing**, introducing risk of delays and bottlenecks. For example, **detachable FAUs (fiber array units) with micro-lens arrays, high-precision optical engine PICs, and special "glue" materials for fiber bonding** are all being developed for CPO and may face yield or reliability issues (花旗：CPO大报告.pdf). Industry watchers caution that unforeseen technical hitches – similar to the delay Nvidia experienced with its NVL (NVLink optical) platform – could push out CPO deployment timelines (花旗：CPO大报告.pdf).

Another risk is the **limited supplier base for critical parts**. Certain optical connector types and fiber assemblies for CPO are currently made by only a handful of firms globally (e.g. Senko or Corning for some multi-fiber connectors) (花旗：CPO大报告.pdf). If demand outstrips these suppliers' capacity or if any single-source component

has a quality issue, CPO system production could be constrained. This is why no one company is expected to take all the market – **multiple suppliers will need to ramp up to ensure adequate volume** (花旗：CPO大报告.pdf). Chinese companies TFC and T&S are positioning to supply a large share of FAUs and fiber shuffles, but **diversifying the supply chain will be important to avoid chokepoints**. The Citi report, for instance, assumes TFC might hold ~40% share in FAU/ELSFP, with the rest eventually split among new entrants like Innolight, O-Net, and international players (花旗：CPO大报告.pdf) (花旗：CPO大报告.pdf).

Geopolitical concerns also loom over CPO adoption in China. Since CPO technology bridges advanced semiconductors and optics, it may be subject to export controls or tech transfer restrictions. U.S.-China trade tensions could affect Chinese access to certain high-end optical components (such as state-of-the-art silicon photonics chips or high-reliability lasers). Conversely, U.S. cloud companies might be wary of sourcing CPO modules from Chinese vendors for security reasons, potentially limiting market opportunities for Chinese firms despite their technical capability. As noted, one impetus for CPO's development was to reduce reliance on pluggable optics largely manufactured in China (Co-packaged optics modules to be $5.5B market by 2027, says CIR | Lightwave). If geopolitical decoupling intensifies, China might double down on domestic CPO development to ensure its data centers can adopt the tech without foreign dependency. This could lead to parallel ecosystems – one led by U.S. firms and another by Chinese firms – which might slow global standardization. **Component shortages** have already been seen in the conventional optics market (for instance, lasers for 800G modules were in tight supply in 2023 (花旗：CPO大报告.pdf)), so similar shortages could hit CPO if laser suppliers or packaging substrates become constrained. Additionally, the complex **packaging and cooling requirements** of CPO mean fewer contract manufacturers are experienced in building these systems. Companies like Celestica (Canada) have started handling advanced switch assembly for 1.6T pluggables (花旗：CPO大报告.pdf); scaling up CPO manufacturing will require investments in new packaging lines, and any hiccups there could be a risk factor.

In summary, the road to CPO adoption must navigate **technical, supply, and political hurdles**. Mitigation will involve qualifying multiple suppliers for key components, international cooperation on standards, and perhaps stockpiling or localizing supply of sensitive technologies. Chinese infrastructure providers will need contingency plans if certain CPO elements face export bans. On the upside, solving these challenges will not only benefit CPO but also strengthen the overall resilience of the optical communications supply chain.

Technological Advancements Driving CPO

CPO's implementation hinges on several cutting-edge innovations in optical networking. Key enabling technologies include **external laser sources (ELSFP)**, **fiber array units (FAU)**, and **fiber shuffle assemblies**, among others. These advancements address the major challenges of co-packaging: how to manage lasers, efficiently couple fibers to silicon chips, and route an explosion of optical signals within a switch.

(LPO vs CPO: Which Will Dominate the Data Center Optical Interconnect? | FS Community) *Comparison of traditional pluggable optics (top), Near-Packaged Optics (NPO, middle), and Co-Packaged Optics (CPO, bottom) in a network switch. In CPO (bottom), optical engines are integrated on the switch ASIC package (or very close to it), eliminating long PCB trace interfaces. This design boosts bandwidth density and power efficiency by shortening electrical distances, but it requires new component approaches (like remote laser units and on-board fiber connectivity) to function reliably.*

External Laser Small Form-Factor Pluggable (ELSFP): In CPO designs, laser light sources are often located outside the main switch ASIC module – this concept is called external laser sourcing. The term ELSFP refers to a pluggable laser module (similar in form to a small optical transceiver) that can reside in a cooler part of the system (for example, the chassis front panel) and feed optical power via fiber into the co-packaged optical engines (花旗：CPO大报告.pdf). Removing lasers from the immediate vicinity of a hot switch chip is crucial; lasers are heat-sensitive and prone to failure at high temperatures. By using an ELSFP, **lasers can be kept at lower temperature and even be made field-replaceable**, improving system reliability and serviceability (Cisco Demonstrates Co-packaged Optics (CPO) System at OFC 2023 - Cisco Blogs) (Cisco Demonstrates Co-packaged Optics (CPO) System at OFC 2023 - Cisco Blogs). Cisco highlights that a remote laser approach lets them passively cool the lasers and avoid having power-hungry temperature control (TEC) devices on each laser, thereby saving energy (Cisco Demonstrates Co-packaged Optics (CPO) System at OFC 2023 - Cisco Blogs). If a laser degrades, an operator can swap the ELSFP module without opening the switch package – a huge maintenance advantage. This architecture does, however, add complexity in delivering the light from the ELSFP to the optical engines (requiring precise coupling). Companies like O-Net, TFC, and others have demonstrated early ELSFP prototypes (花旗：CPO大报告.pdf). As CPO adoption grows, **ELSFPs will play a vital role in providing reliable laser light to many optical engines from a central source**, akin to how one big light source can feed multiple fibers.

Fiber Array Units (FAUs) and Optical Connectors: A fiber array unit is essentially a connector or interface that aligns optical fibers with the photonic chips (optical engines) inside a CPO module. Traditional pluggable optics use a simple MPO connector at the module's face. In CPO, since the optical engines are on the board or

package, the FAU is how fibers physically attach to the silicon photonic chip's surface (often through a micro-lens array that focuses light into waveguides) (花旗：CPO大报告.pdf). Early implementations used fixed fiber attachments, but **the industry is moving toward detachable FAU connectors** – meaning the fiber bundle can be removed/replaced without disturbing the ASIC, which aids manufacturing and repair (花旗：CPO大报告.pdf). FAUs are highly precise components; they must align perhaps **32, 64 or more fiber cores** exactly with tiny optical grating couplers on the chip. TFC Optical has expertise here, having supplied Mellanox and now Nvidia with FAUs that mate fibers to optical engine PICs (花旗：CPO大报告.pdf). Innovations in FAU technology include adding micro-lenses to improve coupling efficiency and standardizing the physical interface so that different suppliers' fibers can plug into the same optical engine design. FAUs are often paired with **multi-fiber ferrules (like MT ferrules)** to organize the fibers. Given their importance, **FAU connectors are seen as one of the "key components" inside CPO** – any improvement in FAU design directly improves the performance and maintainability of co-packaged optics (花旗：CPO大报告.pdf). By 2027, the market for FAUs used in CPO could reach **RMB¥3.0 billion** (roughly $400+ million) in value, underscoring how rapidly the demand for these tiny connectors may grow with CPO deployment (花旗：CPO大报告.pdf).

Fiber Shuffle Assemblies: One often overlooked challenge of co-packaged optics is managing the sheer number of fibers coming out of a switch. A single CPO switch can have hundreds or even thousands of fiber connections when you consider 16 or 18 optical engines, each with many lanes, all needing to reach front-panel ports or other equipment (花旗：CPO大报告.pdf) (花旗：CPO大报告.pdf). Enter the *fiber shuffle* – essentially a pre-arranged, layered fiber ribbon or flexible circuit that routes optical fibers in an organized way. A fiber shuffle can ensure that each fiber from the co-packaged optical engines is cut to the exact length and mapped to the correct output connector, avoiding tangles and uneven path lengths. **Think of it as an "optical backplane" inside the switch.** In multi-plane CPO switch designs, some optical engines are physically farther from certain output ports than others; a fiber shuffle evens out these distances by weaving the fibers appropriately on a substrate (花旗：CPO大报告.pdf) (花旗：CPO大报告.pdf). The fibers are typically embedded or attached onto a thin flexible PCB, with gentle bends and predefined routing. This not only saves space but also makes assembly more repeatable. T&S Communications has invested in fiber shuffle technology and is expected to supply these to companies like Corning (which in turn integrate them for Nvidia and other clients) (花旗：CPO大报告.pdf) (花旗：CPO大报告.pdf). Analysts forecast the fiber shuffle market to reach

RMB¥3.3 billion by 2027 (≈$450 million) as CPO ramps up (花旗：CPO大报告.pdf) (花旗：CPO大报告.pdf). Notably, fiber shuffle pricing is determined per channel or per cassette (a cassette being a bundled group of fibers with MPO connectors). Each high-end CPO switch might use one or two fiber shuffle cassettes, and content values per switch could be in the thousands of dollars (花旗：CPO大报告.pdf). The innovation here is not just in the fibers themselves, but in the packaging method – essentially creating a **modular fiber harness** that can be manufactured and tested off-line, then inserted into the switch as a unit. This simplifies what would otherwise be a wiring nightmare. Fiber shuffles exemplify how **optics is replacing copper cables in internal connections**, continuing the trend of optical solutions moving deeper into networking equipment (花旗：CPO大报告.pdf).

Beyond these specific components, other technological advancements are in play. **Silicon Photonics integration** is at the heart of CPO – advances in photonic integrated circuits (PICs) allow modulators, photodetectors, and drivers to be integrated in the same package as the ASIC. The **OIF's 800G Co-Packaged Optics standard** and other multi-source agreements are driving common design guidelines so that optical engines from different vendors can interoperate. We also see a roadmap toward even tighter integration: what Citi's report calls **Optical I/O (OIO)** for **xPU interconnects** – meaning using optical links not just for switch port interfaces, but for directly connecting computing processors (GPUs, CPUs) inside servers (花旗：CPO大报告.pdf). This could happen in a 2027+ timeframe and would use similar tech (photonic chiplets, perhaps even one fiber shuffle per server rack) to create low-latency optical fabric between processors. In terms of packaging, researchers are exploring **wafer-level co-packaged optics**, where multiple optical engines are integrated on a silicon interposer or even bonded at wafer scale before being diced – IMEC demonstrated such concepts, showing the industry's effort to streamline CPO manufacturing (花旗：CPO大报告.pdf). Cooling innovations (like improved heat sinks and thermal interface materials) are also crucial, since CPO places optics near high-power ASICs and thermal management is complex (Powering the future of data centres — Co-Packaged Optics | APNIC Blog).

In summary, the march toward CPO in China's communications infrastructure is propelled by these intertwined technological advances. **Remote laser modules (ELSFP)** ensure light availability without heat penalty, **FAU connectors** enable precise fiber-to-chip links, and **fiber shuffles** make dense optical connectivity feasible inside a chassis. Combined with progress in silicon photonics and packaging, these innovations are transforming how high-speed networks will be built. China's tech industry, from component makers to system integrators, is actively contributing to and adopting these advancements. In the coming years, as prototypes turn into products, we can expect to

see China's large data centers gradually implement CPO-based switches – initially in AI super-computing clusters and eventually in mainstream cloud infrastructure – ushering in a new era of optical connectivity that keeps pace with the country's immense digital growth (花旗：CPO大报告.pdf) (花旗：CPO大报告.pdf).

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