Forthright scrutiny of the VCSEL business: opportunities & obstacles
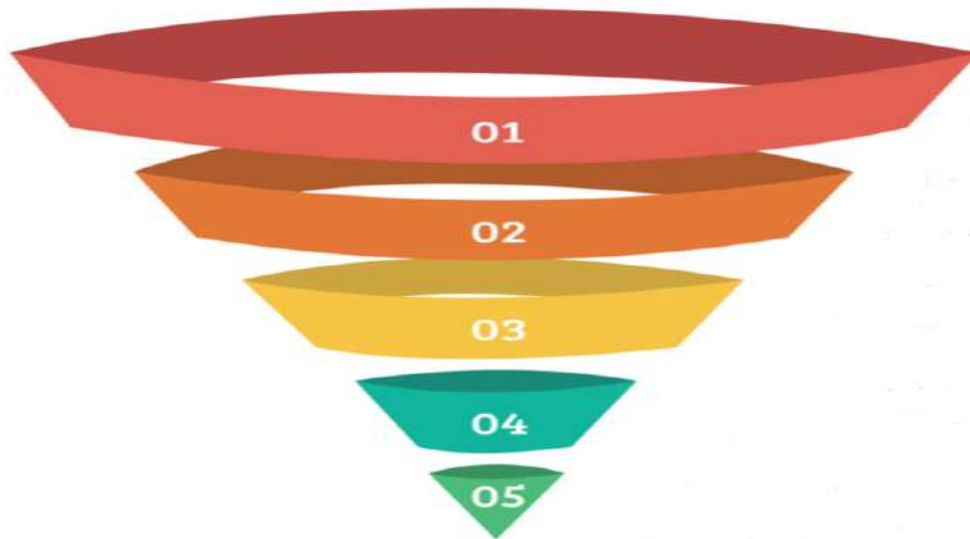
Mark Lutkowitz, Principal

EPIC Meeting in Stuttgart, Germany

October 17, 2019

Overview: Inverted Pyramid Presentation

fibeReality

01 — Future of main VCSEL market sectors

02 — Competitive landscape

03 — Focus on datacom

04 — Smartphone/Consumer outlook

05 — Auto, LiDAR, avionics apps

Major VCSEL Applications & Growth Perspectives

High-Power 940nm VCSEL Outlook

- ## Lots of competitors chasing these devices

  > Building new fabs

  > Demand hasn't emerged as quickly as anticipated

  -- Apple remains primary user & too many focused on this one segment to detriment of others

  -- Tough situation in sitting on large, idle capacity (needs customer like Apple to drive volumes)

- ## 940nm will progressively be bigger market with some growth possible as early as 2020

  > Principal unknown is Apple's drawing board (ex. robots)

Smartphone VCSEL Market Specifically

- No quantum leap expected in short term

  > Volumes not much higher in 2019 compared with '18 and '17

  > Androids increasingly filling in, face-ID side first

  > No step-wise increase expected with world-facing, yet

    -- Impacting a few Android phones with tendency to place in models only 5% of volume

    -- Apple could introduce killer app/part

  > Best case scenario is doubling of VCSEL revenues

Datacom VCSEL Growth

- ## Niche continues growth at historical clip

  > Roughly 10%/year (margins on chips probably much better than 940nm)

  -- Datacom is old-faithful, but not sexy market anymore

- ## 2 areas needing near-term breakthroughs

  > 50-gig PAM4 technology still a year from that nut being completely cracked (for 100G MMF)

  > Still some rollout issues with 25-gig & VCSELs

  -- Some giveback on high-temperature operation

Autonomous Driving VCESEL Opportunities

- Most attractive aspect is confluence of about 50 different sensors slowly playing out

  > VCSELs will be about a half dozen of them

  -- Could be next big distribution channel after smartphones

  -- Available now for gesturing in-cabin/driver awareness, etc.

  -- $300K/year Mercedes first/in 20 years, down to Yugos

  -- VCSEL availability on outside of car looking out could take at least as long as another 3 years

Another Impact of Autos on VCSELs

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- **Each car will be generating probably over 100 gigabytes of data every day**

    > Has to go somewhere

    -- Cannot remain in car for long

    > May not be vision compression with cameras

    -- Can have some anomalies for such critical functions

    > Data storage space will be beneficiary

    -- Corollary market of growth for VCSELs

On LiDAR

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- LiDAR space very fragmented right now

  > Sources of all types and all wavelengths

  > While people talk about high-powered VCSELs

  -- Problem really is LiDAR needs a bigger throw
     and so there is uncertainty

- LiDAR is also quite costly

- Perhaps little hope for meaningful sales of
  VCSELs outside the car

Lots of Smaller, Specialized VCSEL Apps in Military, Aerospace, etc.

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- In aggregate, about a third of datacom VCSEL space, which won't really drive volume

  > Adds diversity/packaging opportunities

  > Interesting for smaller, niche companies, which didn't spend $100M on a fab, to produce VCSELs with unique performance (ex. oxygen sensors)

    -- Talking about as low as $1M/year opportunity

  > Variety of new products will be coming out in the 3D-recognition world

    -- Catering to hobbyists (VCSELs going on drones, etc.)

Competitive Analysis of Major VCSEL Vendors
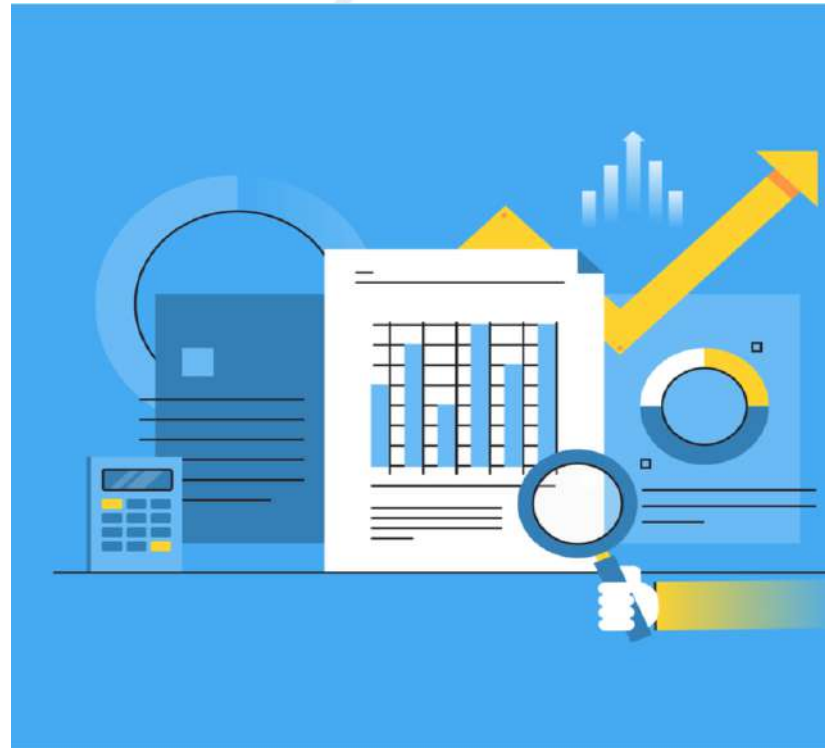
Lumentum's Dominant Smartphone VCSEL Position

- Foundry business model saved it from making early mistakes

- Potential long-term problems

  > No ownership of vertical integration

  > Apple prefers domestic supplier

    -- IP protection & political benefits

  > Price declines despite market position

  > Limited Android growth

  > Early loose lips on margin generation

WIN Semiconductors Showed Everybody Up at Start on 6" VCSELs

- ## Just had better fab/engineering expertise

  > Yields have improved considerably since that time

- ## Like other GaAs producers

  > Cell phone power amps will produce margins

  > Opening up markets to low-margin opportunities can be advantageous to ensure 90%+ fab utilization

  -- Ex. Avago with 0% margin on VCSELs in computer mouses in past (made money on datacom devices)

IQE Overbuilt Capacity

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- Biggest problem for EPI company is like other players, constructed for a flood

  > Instead got a light rain

- Apparent difficulty with continual messing with EPI stack

  > Every time there is a little change

  -- Run risk of technical issues

Major Changes at Finisar (now II-VI)

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- Lost bet on 6-inch VCSELs not happening

- fibeReality picked up some intelligence

  > Finisar stopped supporting datacom customers

  > Lots of VCSEL talent left the company

  -- Including arguably best designer in the world

  -- Risks historic connection with Apple

- Sherman, TX plant intending only 940nm

  > May easily be enough 3" VCSEL suppliers now

  -- Wonder about adequate utilization at fab

A lot of Questions with II-VI & VCSELs

- ## II-VI still appears committed to datacom

  > Feedback from IBM/government work

  -- But only just starting to look under Finisar hood

- ## Marketing stress on 940nm

  > Dealing with too much production capacity

  > Apple likely favors Sherman, TX fab succeeding

  > Newton Aycliffe albatross

  > Warren, NJ fab had been train wreck in past

  -- Had a hard time making HBTs

VCSEL Chips: Big Money Maker for Broadcom

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- Dominant player in datacom bare die space

  > Doing R&D work on 100G VCSELs

- Large supplier to Apple in general

  > Declined to enter 6" 3D-sensor space

  -- Capable, but didn't see adequate profitability

- Industrial apps

  > Separate from main optic chip biz

  -- Industrial Fiber Product Division

Sumitomo VCSEL Biz Taken Out of Mothballs/Wild Card

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- Several years ago bought Emcore assets
  > Shut down in Albuquerque & moved to Japan

- Head of auto cable harness biz: pro-VCSELs

- Very big sales to Huawei generally

- No interest in sensors for now

- Focus on only datacom VCSELs

  > Threat is firms with idle capacity moving into space

    -- Sumitomo can't keep up with 6" fabs

Other VCSEL Suppliers

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- Skyworks in pretty good position from fab perspective with manufacturing expertise
- Limited number of high-quality, high reliability, high-speed (25-gig and above) datacom firms

    > Like TRUMPF/Philips

- ams has advantage with Android customers

    > Offers full turnkey solution

- For BiDi, Cisco Systems sells 855nm & 910nm

Data Communications VCSEL Space

VCSEL Usage by Large Data Centers

- Alibaba uses a very large number of VCSELs

  > In general, Chinese data centers tend to be constrained by space

  > Alibaba wants SR4.2 (2 wavelengths/fiber)

  -- Large enterprises everywhere expected to use this type

- Google is apparently only US hyperscaler, which has deployed a lot of VCSELs so far

  > Including SR4 over OM3 fiber

  > Shifting to 400G-SR8 (8 pair – 1 lambda/fiber)

Microsoft's Plan to Flatten Data Center Architectures

- Multimode fiber ideal for 30m & lower

  > ½ of Microsoft's networking problems involve cleaning singlemode fiber connectors

  > Other hyperscalers likely to adopt DC approach

  > Yet, Microsoft networking leader against its use

  -- Avoid managing 3 part numbers (SMF, copper, MMF)

  -- Prefers 32-channel DWDM duplex solution

  -- Otherwise, no particular prejudice against MMF itself

  -- fibeReality believes Jeff Cox will change his mind

100G VCSELs Could Help Accelerate Elimination of Top-of-Rack Switches

- Appears technically feasible & cost-effective

  > 100G VCSEL demo at ECOC by Finisar

- Significant rise in bandwidth over other VCSEL solutions

- Choice of either 850nm or 940nm

- Being studied by IEEE 802.3

  > Presentation by OFS

  -- "Standardizing a ~30m (TBD) VCSEL PMD will prepare the way for 100m PMD in a future step"

Bottom Line for Hyperscaler VCSEL/MMF Market Size

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- Fiber vendors don't like yields as much with MMF

- Copper still potential play in many cases

- On the pro side:

  > Lower cost/lower power with MMF vs SMF TXs

  > Alignment tolerances about 10x different between SM & MM

  > Silicon photonics not a threat

  -- Concept first mentioned 50 years ago this month

Final Frontier for Datacom VCSELs

- ## Last volume increase: shortest reach links

  > Perhaps all backplane connections can be MMF on massive switch

    -- With uniform electrical interface defined for CPO in very long-term

    -- IBM renewing government project to develop VCSEL-based CPO

  > MMF made for HPC (work on 50G NRZ module)

    -- if reliability issue solved

    -- GPUs, accelerators, memory banks (evolution into 3 tiers vs 2 tiers), etc., all within few meters
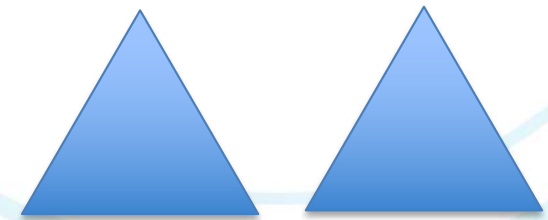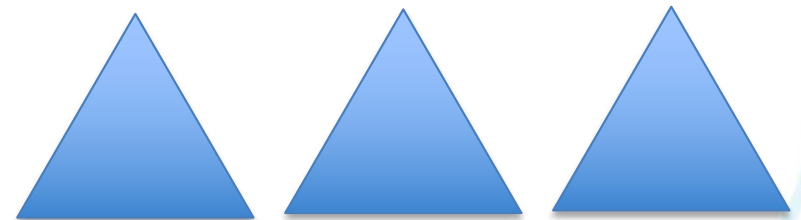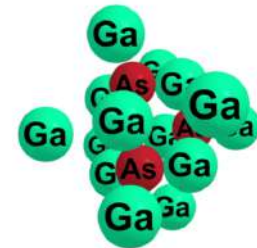
More on Smartphones & Consumer Applications
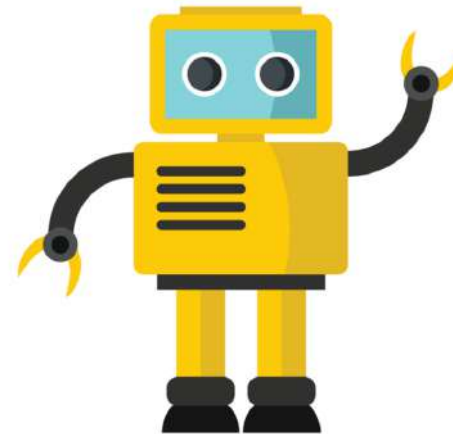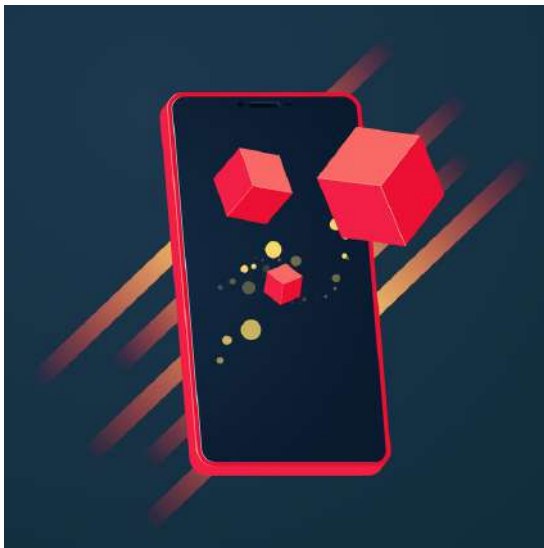
Apple's Unique Situation to Achieve Uniform Process in '17

6" VCSEL Fabs

DATA

Lumentum, Q4 2017: More VCSEL apertures shipped than in all of recorded history

Epi Operations

A lot of Early 6" Yields Were Lost

- Apple leaned kind of heavily on Finisar on 4" to fill initial phone orders

    > Renegotiated contract just to make volumes

- Somebody made simple math miscalculation

    > A lot more inventory in pipeline than originally thought

    -- After initial rush

    -- Really slowed down momentum

Smartphone Pricing and New VCSEL Developments

fibeReality

- Greater VCSEL price pressures

  > Me-too processes insisted by Apple

- Possibly sensor needed for "jaw detection"

  > Miniscule wafer volumes because they are tiny devices (200,000 on a wafer)

  -- Would not materially affect fab costs

- Speculation about other side of the phone camera

- Possible needs for larger die/higher power

Larger Diameter VCSEL Wafers Unlikely to Happen Soon

- Assumption may go to 8" for consumer apps to get costs down further

  > Pulling off 6-inch alone was minor miracle

  > RFIC industry processes 20,000 to 40,000 6-inch wafers/week

  > Maybe VCSELs in its entire heyday, production was several hundred 6" wafers/week

    -- Would be silly to try to lead from optics perspective

    -- As aside, microLEDs are driving some 8" GaAs planning

Closer Look at Automotive & Avionics

Evaluation of Auto OEMs

- Audi is considered a leader in networks
- Ford is second

    > Surprisingly advanced with Ethernet testing lab

- Toyota is one of the most conservative
- Common philosophy similar to satellite folks

    > New technology will not be used unless tested for 10-20 years to avoid questions about reliability

    -- A lot of disdain/concern even for Ethernet robustness (let alone copper & fiber considerations)

Specific Problems with LiDAR & Autonomous Driving

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- ## Extremely long market cycles in automotive

  > New IEEE project could easily go to '24/'25

- ## Possibility of primary computer dropping out/auto firms nervous about crashes

  > Can't say "let's reboot"

  > Need backup that knows everything

  -- 2 redundant processors mirroring each other & huge bandwidth requirement between them

LiDAR Proponents Banking on Government Safety Standards

- Regulation process very slow

- Intelligent vehicle-highway-system in US

  > Began in late '80s

  > Chicago to Florida at 130/hour on guideway with all controls handled electronically

    -- "The technology is here today," according to David Cole, director of the Office for the Study of Automotive Transportation at the University of Michigan, Chicago Tribune, March 19, 1989

    -- Commitment to system by GM & federal gov't

More on Autonomous Driving

fibeReality

- InP-based radar systems probably not cost-effective either

- All the technologies can be spoofed

  > Need to combine all solutions

    -- Even more price pressure

- LiDAR startups may go way of solar firms

  > After burining much VC money spent

Avionics: Generally Higher Value VCSEL Apps

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- Moving more optics on planes, so good opportunity for a small company

  > Looking for very extreme temperature range operations, tremendous amount of ruggedness, & quite high reliability

    -- Last thing you want to do is take panel off plane, go back into wing, etc.

    -- Customers very willing to pay a few dollars more for something they know absolutely works

Thank You!

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