FRONTIER TECH INVESTOR

ISSUE NO. 26 JUNE 2018

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The Thunderchip

The next generation of microchips are here – and they could save the world

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I have a stable of technological innovations which I monitor on a constant basis. What I'm looking for is news that will transform them from being potential investments… into something urgent and relevant to what's happening right now that we can invest in for near-term positive results.

Perhaps "news" isn't quite the right word.

What I'm really talking about is a **catalyst** that can turn a fringe story into the next front-page news. I'm excited to tell you that there were two news stories in May which – combined – have me very excited about this month's issue.

When I heard these stories within days of each other I knew that I had to share them with you because I think we are going to make a lot of money off the back of this theme.

The most important law in tech

The story begins in 1959 when people were beginning to think about what the future of the semiconductor sector might look like.

For the 35th anniversary of Electronics magazine, Gordon Moore was asked to predict how the semiconductor components sector was going to evolve over the following decade. He made his famous call that it was reasonable to expect that 65,000 transistors might be fit on to a quarter inch semiconductor by 1975 because at the time the rate of innovation was doubling every year.

Today the figure is more than 20,000,000,000. That's about as good an example as one might wish for of exponential compounding.

That impressive rate of compounding in the semiconductor sector became

known as Moore's Law. Between 1975 and 2016 it was a benchmark against which the semiconductor sector measured itself.

Up until 2016 the Semiconductor Industry Associations of the US, Europe, Japan, South Korea and Taiwan produced the International Technology Roadmap for Semiconductors. It was literally an index of what they predicted based on the doubling of transistors on the chip every 18 months or so.

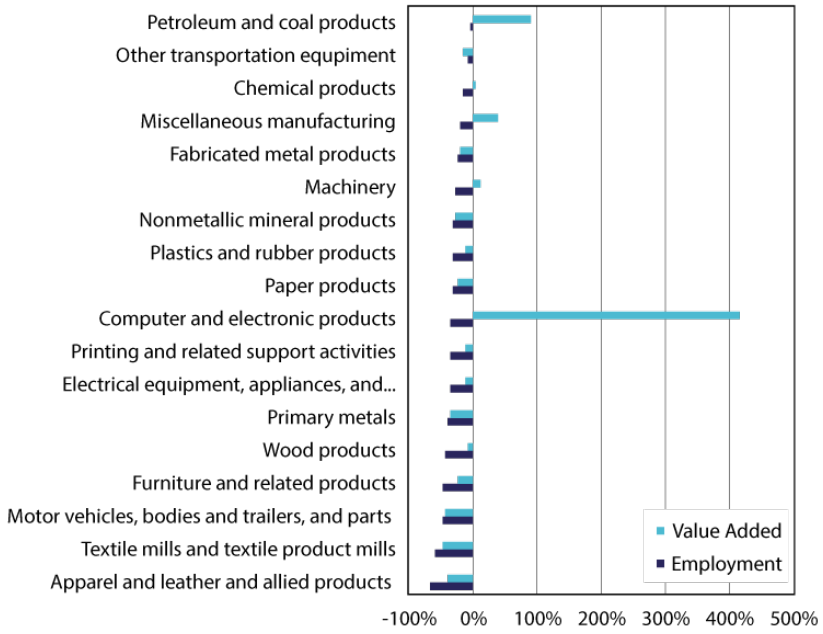
However, in 2016 they abandoned the document because Moore's Law had ended. The challenges of creating chips at nanoscale mean it is now impossible to predict with the same degree of accuracy how the sector will evolve.

It's almost impossible to quantify just how important Moore's Law is to how we live our lives. Let me give you just one example.

Generally speaking the conventional wisdom is that the US manufacturing sector is in fine fettle. However, since Donald Trump ran on a platform claiming China has stolen manufacturing jobs – and gained traction with that argument – I think we can conclude something else is going on. All is not as it seems in the manufacturing sector.

Why?

Susan Houseman at the Upjohn Institute looked into this question and through detailed analysis was able to pinpoint just how much of the manufacturing sector's productivity comes from the computers and electronics sectors.



It turns out that even though very little chip manufacturing takes place in the US any more, the exponential pace of innovation supplied by Moore's Law means it generates a huge chunk of productivity in the manufacturing sector.

In fact, two thirds of all productivity is accounted for by the IT sector. Take a look at the chart I've shared for a graphic illustration of what's happening.

In blunt terms, computer and electronic products – powered by Moore's Law – mask serious deficiencies in the rest of the US economy.

That's great if you work in those sectors (Silicon Valley). Not so much for the rest of the economy – which is what the Trump campaign tapped into.

The problem is, Moore's Law is reaching the end of its trajectory. We're bumping up against the limits of existing techniques and know-how.

How do we solve the end of exponential tech growth?

If a solution is not found to the end of Moore's Law quickly, then the mask that has covered the real performance of the manufacturing sector will be removed and the full scope of the challenges facing ordinary people will need to be laid bare. That won't be pretty.

Little wonder there is a race on to get a solution in the market fast. Failure to come up with an alternative could set the global economy up for its first recession in a decade.

As consumers we marvel at the exponential pace of innovation that delivered incredibly powerful tools at ever falling prices. The birth of the consumer electronics industry has literally transformed the lives of billions of people.

But it comes, literally, at a cost. A big one.

For producers of chips there is another less well-known law which applies to the cost of delivering these innovations. Rock's Law, also known as Moore's Second Law, states that the cost of a semiconductor chip fabrication plant doubles ever four years.

In 2015 the cost of a chip plant was $14 billion so next year it will be $28 billion.

It makes sense when you think about it. The level of ingenuity and engineering involved in making Moore's Law happen is expensive. And those expenses are themselves exponential.

As the race to invent and install progressively more innovative gates at ever smaller widths heats up, these costs act as barriers to new entrants which are growing higher by the day. At a starting cost of $28 billion, getting into the semiconductor business is too expensive for small companies.

That means they have only two options for success.

- They can try to be first to iterate on the next leg of Moore's Law so that one of the established chip manufacturers will buy them out.
- They can try for something completely different in the hope that they can completely subvert the industry and make it into the ranks of the tech elite. That's what might be considered the high risk/high reward alternative. The good news is that there are a number of startups shaking things up that have the potential to revolutionise the chip sector.

Something totally new is required. That means new tech, new engineering, new equipment and new ideas.

Catalysts for change

One of the news stories I saw last week was that Taiwan Semiconductor is now shipping 7 nanometer chips to Apple. Advanced Micro Devices has launched its own 7nm chip for both CPUs and graphic cards, which is also being manufactured by Taiwan Semiconductor.

Intel is still shipping 10nm chips but tends to differ on how a node is defined so it is reasonable to say all three have similar performance chips in the market.

Why is all this significant?

Well, a silicon atom is 0.2nm wide and the theoretical limit for semiconductors is about 1nm. However, the technical challenges of getting to 1nm are so daunting that there is a legitimate argument that with the release of 7nm chips we have reached the limits of what Moore's Law can achieve.

Something totally new is required. That means new tech, new engineering, new equipment and new ideas.

Just about all companies are working on 3D architecture, which will increase the real estate on a chip allowing more transistors. That's an elegant solution but it is a perversion of Moore's Law.

Something outside the box is needed if the pace of innovation is to persist on its exponential curve, and that is what I'm writing to you about this month. It really is about shedding some light on the problem.

I mean that literally. It turns out *light* could be the answer.

Optical computing could give Moore's Law a new lease of life

Current silicon chips use electric currents in their signalling. But light travels about ten times faster than an electric

current flow. **This means there is the potential to speed up processing times by ten times if optical computers can be brought to even greater commercial reality.**

Optical computing is one of the core sectors driving at developing neuromorphic computing. In layman's terms we're talking about using light to create computers that think like humans.

In the words of Austin Powers' Dr. Evil, we are talking about "lasers". Optical computers use photons of light to transfer information. We already do this with fibre optic cable but the challenge in developing this technology is in how to do that inside a computer chip.

There is an additional potential benefit in that visible light and infrared pass through each other so they can exist in the same space, whereas electric currents must be guided around each other so they tend to be bulkier.

So if they are so great, why don't we have them in our homes? Simple. One of the challenges optical computers have is that they are so quick that a solution is required to slow down the light so it can be processed by the computer.

In other words, they're *too* fast. We haven't been able to harness that raw speed and power properly. But that's changing.

Interesting things are happening in the market right now that have greatly enhanced the potential that we will hear a lot more about light-based computing, optical computing or photonics in future.

Researchers at the University of Sydney think they might have an answer for how to get optical computers into your home. They aim to slow down the light as it enters the chip by turning it into sound waves. They describe it as the equivalent of turning lightning into thunder.

> *"For [light-based computers] to become a commercial reality, photonic data on the chip needs to be slowed down so that they can be processed, routed, stored and accessed," said one of the research team, Moritz Merklein.*

> *"This is an important step forward in the field of optical information processing as this concept fulfils all requirements for current and future generation optical communication systems," added team member Benjamin Eggleton.*

So what do faster computer chips mean for the world? In a nutshell it will change our relationship with data and speed up the race to create artificial intelligence (AI).

The basic way a tradition chip works is that it takes a big problem and breaks it down into lots of small problems that it then solves sequentially. When we are talking about AI and trying to think like a human, the number of calculations gets very large, very fast.

New state-of-the-art optical computers come at the problem in a different manner. Through a lattice of what can be considered lenses, the light passes through the entire array in one go. Tiny changes in the phase and/or path of the light are measured and the answer is returned in the time it takes for the light to transit the circuit.

These kinds of circuits are not designed to answer simple questions like your typical Google search, but they are ideal for the large data set problems which AI and deep learning algorithms use.

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A Silicon Valley startup, Fathom Computing, is going after the neural network market, again by focusing on the kinds of datasets that are very large and prove challenging for conventional computing.

Fathom claims that its hardware can "significantly outperform state-of-the-art GPUs," adding

that "a single Light Processing Unit (LPU) has the potential to replace the deep learning work of an entire supercomputer." It has a prototype but it will be at least a couple of years before a commercial cloud-based service is available.

The other piece of news I heard last month was that Intel has announced it is shipping its first photonic transistors in bulk. It had announced at last year's Intel development conference that this was on the way and now it is in the market.

In very simple terms this means that Intel is the first company in the world to get an optical computer component into the market and has identified a clear business case for commercialisation. By doing so it has raised the bar for every startup seeking to make waves in the data centre market. They now have to reach further and dream bigger because Intel has just carved out a big piece of the data centre market for itself.

Even more important, we can see where the trajectory of development is now heading. The first piece of news I was talking about focused on companies trying to iterate on Moore's Law, which they have to know is getting ever more difficult. Meanwhile, Intel is pushing the boundaries of the possible by bringing optical components to the data centre market.

Intel's new 100 gigabit connectivity transistor allows for much faster connectivity between chips in the server farm. The company has been very clear that this is totally new architecture and it expects to be able to iterate on it for years to come. We can anticipate the news on the commercialisation of optical computing to come hot and heavy over the coming years.

I can't tell you how important that is. It represents a whole new income stream for the company and it's why it is this month's buy recommendation.

The components make use of Intel's hybrid silicon photonics solution. Silicon is not a light-emitting element, but through a chemical treatment the Intel team has been able to get silicon to emit light when an electric charge is applied and that forms the basis for its optical transistors. The first medium of data transportation was copper and fibre optics which have been around for years, but the new optical components are the next leg in longer distance transportation.

Within a data centre, which can be up to hundreds of acres in size, copper is still appropriate for distance of anything up to three metres. Fibre optic gets you off the rack and down the lane but optical components are required if you are going to manage communication along the rows and down the alleys of these vast buildings. That's why 100 gigabit connectivity moves the needle in data centre performance.

Intel has over 16 years of hard graft integrated optics directly on to the silicon and also introduced lasers at the wafer level. That has removed the need for active alignment. In other words, the laser will always hit its target.

It has the capability to manufacture these components and test them at the wafer level. That's the key success of this endeavour because by miniaturising the production methods it has been able to deliver volume manufacturing at low cost.

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Buy Intel

It is important to think about where the money is being made in today's semiconductor industry.

We all have phones, tablets, laptops and TVs and the number of routers is increasing exponentially as the number of internet-connected devices has exploded. That's a highly competitive field dominated by the likes of Apple and Samsung.

However, one of the biggest

growth sectors for chip manufacturers is in data centres. This is the first commercial use case for optical components. It's also why all the startups I've been telling you about are focusing on the data centre space. Let's explore why that is.

Think about the kind of information processing needs of companies like Amazon, Alphabet/Google, Facebook, Microsoft Baidu, Alibaba and Tencent. These represent some of the biggest companies in the world that are rolling out progressively more AI solutions.

The most important thing about new services like Amazon's Alexa smart speakers or Apple's Siri, Google's smart speaker or Microsoft's Cortana is that the software running these services is not hosted on the device in question but rather runs over the cloud.

In fact, these companies are called Intel's Super 7 because they are part of the company's Early Ship programme. They get new chips up to six months before they are released to the wider market and when they buy, they buy a lot.

The race to gain market share in the smart services sector is running on the drive to build the most up-to-date data centre. Perhaps most importantly, these companies are not waiting five years to update their servers but are on a much quicker replacement schedule.

When you are running a data centre, the question is not only about how fast each individual component of the network is, but in how fast they can communicate with one another. That's particularly important for companies running big data questions or attempting to perfect AI systems. Everything from self-driving car simulations to predicative drug testing is dependent on data centres being capable of running at the greatest efficiency possible.

Let's put some figures on this growth.

Companies and funds invested at least $18.2 billion in data centres in 2017. That was more than the previous four years combined.

A couple of years ago Diane Bryant, Intel's former head of data centre business, was quoted as seeing companies like the Super 7 buying more than 10,000 servers a year. Today they are buying millions of servers and data centres are approaching the size of small cities.

Intel has about 50 more customers that have since set up their own data centres. I'm talking about companies like Uber, Pinterest, JD.com, Airbnb and Netflix. They would then be looking at a replacement cycle of about every three years instead of the traditional five years.

Intel's data centre business turned over $19 billion in 2017, which represented 30.4% of total revenue for the company. My belief is that within the next few years, data centres will become the biggest part of Intel's business and that growth will be led by its optical components.

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Client computing is the company's biggest revenue stream at 54.2% of revenue in 2017, but it is has been static for the last four years. It is the data centre business that is accounting for all the company's growth and with the release of silicon photonic transistors, I believe this is set to be a booming business.

You'll recall that Intel bought one of my previous recommendations, Mobileye, to gain a foothold in the autonomous vehicle market and it continues to invest in that sector. By buying Intel we are regaining at least tangential exposure back into the autonomous vehicle sector.

I'm coming to you this month with Intel as a play on optical computing, but it has another key innovation that has been making waves. That is its 3D XPoint memory/storage hybrid.

Developed by Micron Technologies and Intel, the 3D XPoint delivers up to ten times faster performance than what is in use today within data centres and is up to 1,000 times more durable. It also comes in at about half the price of NAND flash storage so it fills an important niche within the data centre market and further boosts Intel's claim on that sector.

There have been significant waves made about the potential for memristors to revolutionise memory and computing for the last few years. HP Enterprises, for example, has been among the chief champions of the technology. However, it is not yet commercial so I have not recommended it, but Intel's 3D XPoint is at least a partial play on the evolution of memristor technology.

The risks with a company like Intel is that demand for data centres subsides from the heady expenditure of 2017 or that competitors capture some of the company's market share.

The barriers to entry in the chip manufacturing sector are high but not that does not mean there isn't competition. Everyone knows that Moore's Law is finished so there is intense rivalry to come out with a new solution. Since the benefit of iterating on previous methods is no longer cost effective, that increases the potential that totally new structures will open up, which is a risk for a company like Intel.

Chip manufacturing is now a more uncertain business than it has been in years. That carries both risks and rewards. Intel's data centre business is growing impressively, but its legacy business of providing chips for PCs and tablets is at risk from changing consumer trends – so if I were to be worried about one part of the business, that would be it.

The company has been growing its dividend by over 8% in the last year and it currently yields 2.1%.

My target over the next 12 months is $75, but over the next five years I believe the share will trade at $250 as the full potential for its innovations in optical computing and storage/memory are more fully valued by the investment community.

Action to take:	**buy Intel Corp**
Ticker:	**INTC**
Price as of 5 June:	**$56.60**
Buy up to:	**$65**
52-week high/low:	**$57.59/33.23**
Market cap:	**$263.6 billion**

Figures accurate as of last market close: 05.06.2018

Past performance:

Data as of 28/03/2018

Energy

Company	Ticker	Rec Date	Price Then	Price Now	Gain/ loss %
Orocobre Ltd	ORE. AX	07/04/16	A$ 2.92	A$ 5.86	100.68
Ormat Technologies	ORA on NYSE	06/06/17	$58.79	$50.90	-12.59
Smart Meter-ing Systems	SMS LN	03/10/17	735.5p	803p	9.88
Sherritt Inter-national Corp	S CN	06/02/18	C$1.18	C$1.28	8.47

Technology

Company	Ticker	Rec Date	Price Then	Price Now	Gain/ loss %
Cyberdyne	7779	30/05/16	JPY 2,353	JPY 1,371	-41.73
IBM	IBM LN	07/06/16	$153.33	$143.70	1.40
SAIC	SAIC US	05/07/16	$58.20	$87.67	54.90
Garmin	GRMN US	02/08/16	$55.75	$61.69	17.06
2U INC	TWOU: US	06/02/17	$33.25	$93.31	180.63
Cisco Systems Inc.	CSCO: US	03/04/17	$33.80	$43.67	33.67
Advanced Micro Devices	AMD US	26/07/17	$14.76	$11.59	-21.48
Microsoft	MSFT	31/07/17	$73.04	$102.19	42.17
Northrup Grumman	NOC US	06/07/17	$301.66	$329.19	10.15
Intel Corp	INTC	06/06/18	$56.60	$56.60	0

Medical

Company	Ticker	Rec Date	Price Then	Price Now	Gain/ loss %
Autodesk	ADSK	19/07/17	$108.83	$136.80	25.70
Abcam	ABC	07/03/17	907.5p	1277p	42.22
Illumina	ILMN	04/09/17	$207.15	$279.10	34.69
PureTech Health	PRTC-L	09/01/18	155.75p	155.50p	-0.16
Agios	AGIO	06/03/18	$84.23	$93.43	-12.50
Becton Dickin-son and Co	BDX	03/05/18	$221.35	$227.72	2.88
Canopy Growth Corp	WEED :CN	21/03/18	C$33.11	C$39.50	19.30

Moonshot

Company	Ticker	Rec Date	Price Then	Price Now	Gain/ loss %
SolarWindow	WNDW	07/04/16	$3.96	$4.36	10.10
Alkane Resources Ltd	ALK: AU	05/09/16	AU$ 0.31	AU$ 0.25	-19.67
Editas	EDIT: US	07/03/17	$21.02	$38.33	80.12
Haydale Graphene Industries	HAYD	02/5/17	178.5p	99.50p	-44.26
Superconduc-tor Tech Inc	SCON	28/03/17	$0.95	$0.95	-1.07

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