

# OVERSEAS

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海外·特稿



## 量子计算将引爆金融交易革命

文 | 泰德·普林斯

### 高频交易之功过

在美国，至少一半的股票买卖是以计算机化的高频交易 (high-frequency trading, 缩写为HFT) 方式进行的。人类交易员发起的交易总是被电脑交易员抢占先机，高频交易商因此赚得盆满钵满。与电脑同场竞技的时候，参与市场交易的自然人总是处于劣势。但是从另一个角度



D-Wave 量子计算机的外观。

看，高频交易的存在对美国股市保持全球领先地位的贡献颇大，在这种合法的交易方式激励下，券商必须时刻提高自己的竞争力并跟上金融服务创新的市场大势。

巨量且快速的交易不但适用于在股票市场套利，还让债券市场及其他金融市场也有了做套利交易的价值。它改变了传统的证券交易规律

和套利方式，进而影响了人们的投资及并购选择。虽然这种交易方式不利于小投资者，但小券商也因此有了与财力雄厚的大券商掰手腕的本钱。所以，高频交易既是市场旧秩序的破坏者，也是新秩序的建立者，它有助于平衡市场各方的竞争实力。

高频交易虽好，但也存在一些重大缺陷，除了将人类交易员同行置于不利的竞争地位之外，它的盲目发展对整个市场来说也具有危险性——一旦短时间内发起的数十亿笔交易在执行中出现差错，可能会引发市场崩溃，这种情况在美国不是没有发生过。总之，高频交易既能让股票市场保持活力和竞争优势，也能轻而易举地毁掉它，真可谓集天使与魔鬼的个性于一身。

为了保护小投资者的利益，目前中国的股市监管者对高频交易行为的监管很严格。但是，赴美上市的中资企业免不了要参与高频交易，否则就无法保持股价的竞争力。高频交易已是境外市场的主要交易工具，这种潮流不可逆转，中国的股市监管者也应当继续研究开展高频交易的监管策略。

## 量子计算登场

高频交易对计算机性能和通信服务质量的要求非常高，基础计算效率直接制约着这一交易方式的发展。如今，IT技术正迎来一个发生质变的临界点——量子计算机的诞生将从根本上提高计算的能力与效率。

谷歌现在装备了加拿大D-Wave公司生产的D-Wave 2X量子计算机，该计算机拥有1000量子位的处理器，是迄今为止运行速度最快的计算机。量子计算机强大的功能令人心生敬畏，连谷歌都还不知道如何充分利用其运算能力。它的诞生必然会掀起巨大的创新浪潮，每个不想落后于世界的国家都应当抓住机遇发展这一



2013年1月4日美国股市收盘前夕，8000只股票在0.05秒内收到来自高频交易商的20万次询价及报价。



2013年7月10日10时39分20秒，高频交易商突然开启“欺骗”算法参与苹果公司股票的交易，所有买卖委托单均被其截留，图中可以看到由此发生的股价变动和交易频次变化。

来源：Nanex Research

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CEO



## 背景资料

### 量子计算机

量子计算机是一种使用量子逻辑进行通用计算的设备。与传统计算机相同，量子计算机也由存储器和运算器组成，但存储内容和逻辑门与传统计算机有所不同。在传统计算机中，信息以二进制数据表示，每一个二进制数据位的0或1由电平的高低决定，每个数据位要么是0，要么是1，二者必居其一。而量子计算机的二进制数据位（量子位）的0或1由电子或原子的自旋状态或二能级系统的基态和激发态决定，由于量子力学中存在叠加态，所以数据位可能是0，也可能是1，还可能同时是0和1。由此，对于n个数据位的存储器，传统计算机只能存储一个n位二进制数，而量子计算机能同时存储 $2^n$ 个n位二进制数。同样，对传统计算机来说，每次操作只能处理一个n位二进制数处理，而量子计算机能同时处理 $2^n$ 个二进制数。

量子力学叠加态的存在大大提高了量子计算的效率，实现了连续变量和真正意义上的并行计算，一次运算可以处理多种不同状况。一台40量子位的量子计算机，能在很短的时间内解开1024位传统计算机需要花数十年才能解决的问题。

### 高频交易

高频交易是指从那些凭借人为反应无法利用的极为短暂的市场变化中寻求获利的计算机化交易，比如，利用某种证券买卖价差微小变化，或某只股票在不同交易所之间的微小价差来获利。高频交易是一种全自动的程序化交易，通过事先编写的各种交易策略，用最快的速度取得交易所的行情信息，若电脑高速分析后认为需下单，则立即生成委托单送向交易所，其最短的持仓/反应时间可以达到纳秒（10亿分之1秒）级，买卖差价可低至1/100美分。

高频交易在交易所内部完成，凭借交易速度获利，属于合规的交易操作。根据美国证券交易委员会的描述，高频交易有如下特点：使用超高速的复杂计算机系统下单；通过主机托管使用直连交易所的数据通道；平均每次持仓时间极短；大量发送和取消委托订单；收盘时基本保持平仓。

技术。

实际上，D-Wave不是真正的通用型量子计算机，它是介于传统计算机与量子计算机之间的一种“混合”产品，与传统计算机相比，还没有具备压倒性的优势。科学家在这一领域的探索仍在继续，IBM也宣布制造了一台处理器为5量子位的量子计算机，并于今年5月初面向全球用户开放了在线访问功能。投身于此项研究的企业还有很多，阿里巴巴也是其中之一。

可以肯定的是，很多大国的情报机关都在参与研发量子计算机，用它来破译密码简直是小菜一碟。美国国家安全局（NSA）已公开承认在做这方面的工作，更多国家对此秘而不宣，说



不定它们的技术水平已经走在了美国前面。

去年7月，阿里巴巴和中国科学院在上海联合设立了量子计算实验室，力争在2020年前研发出50量子位的量子计算机。这个目标看似比D-Wave 2X逊色很多，但它们要研发的是通用型量子计算机，与D-Wave现有的混合型产品是完全不同的。

### 高频交易 + 量子计算 = ?

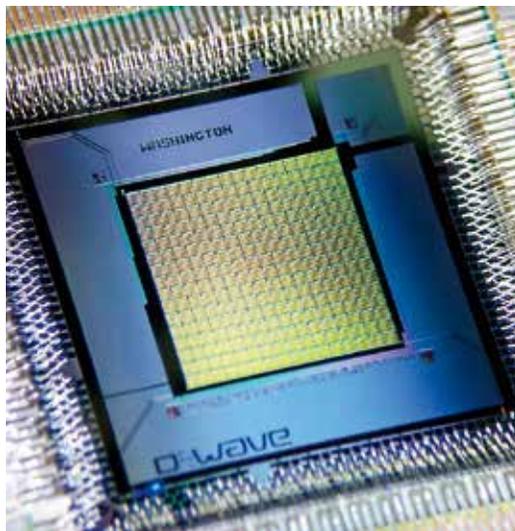
分别说罢高频交易和量子计算机，让我们再来看看当两者结合起来会发生什么。使用量子计算机操作的高频交易，其交易速度显然会比现在更快。现在的高频交易反应时间已经是毫秒、微秒计，比这还快……那事情就变得更有意思了。

量子计算机的先进之处在于它可以在同一时刻用叠加的方式来做大量计算。当我们讨论使用量子计算机来实现快速交易时，这里所说的“快速”基本上意味着瞬时，不管有多么大的计算量，都能以几乎零耗时的速度解决。

说起股票交易的计算工作量，其实也不难想象，当计算机的处理能力达到量子级别之后，或许它能轻松地预测出未来100年全球所有股票的价格走势，或许能统计出明年所有交易对手掌握的合约价值，或许能同时计算出目前全球每只股票做空和做多的策略。与之相比，目前市场上正在开展的高频交易，其速度就像乌龟爬了。所以，主打高频交易的券商们很快会掀起采购量子计算机的热潮，它会成为金融工作者都想拥有的大玩具。不用量子计算机所高频交易的券商，很快就会在竞争中落败。

随着量子计算级别高频交易的发展，套利交易方式会发生新的革命。实际上，套利交易概念本身将被改写，因为量子计算机是在同一时刻叠加计算，套利的时差已不复存在。再强调一遍，量子计算级别的“快”，与我们现在对的“快”理解是完全不同的。

对于中国股市来说，新的问题来了。在量子



计算时代，如果继续对市场中的高频交易活动设限，中国企业将很难参与全球市场竞争，西方公司将因此获得巨额利益。因此，中国的资本市场亟待升级，监管部门需要立即动手研究，找到既能保障小投资者利益，又能正常开展高频交易的办法。只有这样，中国企业才能跟上世界新技术革命的步伐。

退一步讲，即便不放开高频交易，中国企业也应当开始研究如何利用量子计算机来开展业务。不仅在金融服务领域，量子计算机在各行各业都有巨大的用武之地，正如上文所说，它拥有强大的运算、统计、预测能力。如果竞争对手使用量子计算机，而你不用，就会被对手看光所有底牌，而你自已处于两眼一抹黑的境地。

高频交易可能引发市场崩溃确实是个大问题，无论企业还是政府都不愿看到这种情况发生。我们应当在业务发展的过程中寻求解决之道，而不是一禁了之。面对量子计算掀起的新商业浪潮，越早加入就越能获取有利的竞争地位。

### 量子计算时代的喜与忧

在商业领域应用量子计算技术是一个宏大

**高频交易可能引发市场崩溃确实是个大问题，我们应当在业务发展的过程中寻求解决之道，面对量子计算掀起的新商业浪潮，越早加入就越能获取有利的竞争地位。**



课题，不是这篇小文能够解决的。量子计算机能做的事远超我们现在的想象，所以企业如何利用这一技术，还有待于科学家与企业家慢慢研究。目前能够确定的是，量子计算时代的序幕即将揭开。这样一个时代的商业特征还需要慢慢研究，总地来看，我的浅见如下：

### 有利之处

- 一旦找到合适的运转模式，量子计算将制造出大量全新的商机、股市投资以及另类投资机会；
- 它将改变套利行为的性质潜在获利能力；
- 我们将有机会掌握衍生品交易和虚拟经济的真谛。

### 不利之处

- 先人一步的市场交易更容易实现，更有效果，同时也更难以被人察觉；
- 交易员酿成大错的机会更多，每次失误都可能毁掉全球市场；
- 未经授权就代表机构进行交易的“流氓交易员”行为会更多，交易规模也将以往更大。想想看，若是出现几笔上万亿美元的流氓交易，

市场会受到怎样的影响？

- 洗钱犯罪将有所发展，黑客等网络金融犯罪也可能会愈加猖獗，像今年2月曝出的孟加拉央行的美联储账户遭黑客攻击失窃8100万美元的案例，未来恐怕还会更多。

### 市场交易者的坏消息

- 各国政府将大大收紧监管尺度；
- 由于不得不遵守日益严格的监管，原本就在收缩的交易与投资收益率将继续下滑；
- 在未来，“太大而不能倒”的金融机构的标准会比现在更宽泛，因为仅有几个交易员的公司也有可能涉及巨大的交易量，甚至还会出现“太大而不能倒的个人”。这意味着无论交易机构规模大小，都将面临比现在更大的监管压力。

### 拥抱量子计算时代

上面所说的情况看似都属于未来世界，但既然谷歌已经开始使用量子计算机，未来离我们也就不远了。可以肯定的是，短短几年之内，量子计算机就将投入普遍使用；还可以肯定的是，量子计算机堪称恐怖的性能与力量会对人类生活产生巨大影响，而由此衍生出的各种影响会更加深刻。

这种能够实施大规模并行计算的设备前所未有，它赋予人类新的权力。为了正确有效地发挥量子计算机的作用，我们必须跳出问题本身去思考，这也有待于我们开展长久、艰苦并且充满想象力的研究。在这场竞赛中获胜的国家与企业，将有能力在全新的领域解决全新的问题，其人民与员工将深深受益，政治、经济、社会也会因而远离由发展带来的各种困扰。

量子计算机技术象征着绝对的进步力量，它的出现将提升人类的整体生存状况。但是，要达到这种效果，还需要政府、企业严肃认真地展开探索，寻找善用这一工具的正确途径，否则将是一场空欢喜。■



左图：D-Wave 2X 量子计算机装备的 1000 量子位处理器。  
右图：中国科学院 - 阿里巴巴量子计算实验室的科学家在制备并研究极低温分子。

# **“Quantum Computers Will Soon Revolutionize Trading and Arbitrage”**

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**May 2016**

## Stock Trading Faster Than a Speeding Bullet

In the US at least half of all stock trading is conducted using high-frequency trading. This is a practice in which the trading is done purely by computers at very high speeds. This means that the computers can always beat trades initiated by human traders which gives HFT traders a big advantage in the market. It also means that individuals who trade in the market are at a big disadvantage. But in the US the advantages have been so great that HFT trading is allowed as a way to allow stock trading companies to become ever more competitive and to keep up the pace of innovation in financial services.

But there are some major disadvantages with HFT. It disadvantages small investors for one thing. For another, it's dangerous for the market. With potentially billions of trades being executed things can go wrong and it could precipitate a market crash. In fact this has happened at least a couple of times in the US. We now realize that HFT could actually bring down a national stock market and potentially even global markets. Yet on the other hand, if a company doesn't do it, at least in the US, it will lose to its competitors.

HFT has certainly changed the nature of equity trading and thus of equity arbitrage which thus impacts investing generally as well as M&A. It has opened up new approaches to arbitrage not only for stocks but also for bonds and other financial instruments. Although HFT puts small investors at a disadvantage, it also allows small companies to compete effectively against large countries, even if they are better capitalized. So HFT is also a disruptor and great equalizer.

In China the regulators have wisely chosen to not allow HFT. This is because they are concerned about small investors. But any Chinese companies who wish to trade stocks on US stock markets will still need to conduct HFT if they are to be competitive. So the fact that HFT is a major factor in overseas trading means that Chinese regulators will need to take HFT into account when forming their own regulatory strategies.

## Traditional Computers are Actually Really Slow – But that's About to Change

But HFT requires fast computers and communications. So everything is dependent on the power and performance of the underlying computers. We are on the edge of a massive change in

computing which will radically increase the power and performance of computers. This is due to the emerging class of quantum computers.

Google is now running the D-Wave “quantum” computer it acquired from Canadian company D-Wave. It’s rated at 1000 qubit. A qubit is a rating of computer speed for quantum computers and 1000 qubits is very fast, the fastest quantum computer ever. On the scale of quantum computers that’s awesome. Google is still figuring out what it can do with it. That doesn’t mean running big spreadsheets by the way.

Quantum computers can do things we haven’t even thought of yet. Quantum computers are definitely going to spawn a huge new wave of innovation. So this is a field where every country needs to be working.

There’s a wrinkle though, actually a pretty big one. The D-Wave is not seen by the purists as being a true quantum computer. It’s a hybrid and as such it doesn’t beat conventional computers on many types of problems.

But the race is on. IBM claims to have a real quantum computer. It’s widely suspected that a number of private companies are well-advanced. One is Alibaba, see below.

More to the point we can be pretty sure that the intelligence agencies in the US, Russia, China, Israel and others are also well-advanced in their development of a machine that can be used for code-breaking and the like. The NSA in the US, the best-known intelligence agency, has already been confirmed to be building one. So we can be sure that the other countries aren’t far behind. In fact it’s quite on the cards that one or more could be ahead of the US.

China has already started building a quantum computer in a new laboratory in Shanghai. This is a joint venture between the Chinese Academy of Sciences and Alibaba. It is aiming at a quantum computer with a performance of 30 quantum bits (qubits) by 2020. Although this sounds like it’s much less powerful than the D-Wave computer, they are almost certainly using definitions that are different since the Chinese computer is to be a “pure” quantum computer whereas the D-Wave is a hybrid.

Stock Trades in Zero Time?

So where are we going with all this? It looks like HFT will soon get a big lift from quantum computers. So it will get faster. Now that’s when things get really interesting. What do we really mean by “faster”?

The nature of quantum computers is that they can use the phenomenon of superposition to do a huge number of computations all at the same moment. So when you talk about using a quantum computer for speedy trading, “speedy” means something totally different. In many cases it means instantaneous, no matter how big the problem.

It all depends on the problem. But it’s conceivable that it could be applied to a problem such as predicting the values of all stocks in the world for the next 100 years in one calculation. Or it could calculate the values of all counterparty contracts in the market for the next year. Or

simultaneously go short and long on every stock in the world, maybe without people even knowing it.

In other words, suddenly HFT is going to look painfully slow, In order to get back into the race the HFT-ers are going to have to acquire one or more quantum computers. It's going to be the new toy for financial services companies' grownups. If you aren't doing HFT with quantum computers, you won't compute at all.

Here's another thing. Once you have a quantum computer, totally new types of arbitrage are going to open up. In fact the idea of arbitrage itself is going to change. That's because quantum computers can in certain circumstances be used to introduce and leverage time dilation (maybe do things out of synchronization with normal concepts of time). So if you think you're going just do things faster, think again. You're going to have to do them different, very different.

That means even if China doesn't want to allow HFT in China, its companies will still be competing against overseas companies that are using HFT, but this time based on quantum computers. This will mean that those overseas companies will not only have the advantage of massively great performance; they will also be able to do things that Chinese companies cannot since they are based on an HFT approach. So in China there will need to be a big move to see how HFT can be introduced in a way that does not disadvantage small investors but that also allows Chinese companies to take advantage of this revolutionary new technology.

And even if China never allowed any form of HFT, Chinese companies will still need to use quantum computers for trading. As I mentioned above there are numerous applications of quantum computers in financial services and trading other than for HFT. For example, the value and exposure of counterparties is a major issue globally in the derivatives markets.

Both companies and governments want to solve this issue in order to fend off the danger of market crashes. Without doubt many of these approaches will be integrated with high-speed trading just between companies for purposes other than buying and selling stocks. Chinese companies will need to be able to enter these markets if they are to get the advantages of the new quantum computing approaches.

#### Quantum Computers Will Revolutionize All Financial Services, Not Just Trading

Now I'm definitely not the right person to be talking to about what they can and will actually do. But we can say one thing for sure. They will do things that are unimaginable right now in the investment and equity prediction spaces, inter many alia. And it will all happen pretty soon.

But here are a few odds and ends that occur to me as being issues that are going to emerge as quantum computers are deployed.

The good news:

- Quantum trading will open up new opportunities for active investing once quants figure out how to make it all work.
- Same thing for alternative investing.
- It's going to change the nature and potential profitability of arbitrage.

- We might all actually get to know the real exposure from derivatives, synthetics and exotics.

#### The bad news

- Trading ahead of the market will now become vastly more simple, powerful and hard to detect.
- There's going to be some huge mistakes made by traders, any one of which could break the markets globally.
- The problem of rogue traders is going to be much more difficult and serious. Instead of trades for a few million maybe they will be for a few billion, or even more. How about a rogue trade for several trillion that goes wrong?
- This is going to lead to serious issues in money laundering, and other computer-enabled criminal acts such as digital theft (c.f. the IMDB mess in Malaysia and the recent Bangladeshi central bank heist).

#### The terrible news (for traders and their sponsors):

- Governments everywhere are going to significantly increase their regulatory efforts.
- Trading and investment services are going to have to ramp up their compliance by a huge amount, which will make their already-diminishing earnings look even more pitiful
- "Too big to fail" is going to mean companies that are much smaller than right now. A company with just a few traders could well be too big to fail – maybe it can't fail even if it's one person. That means a lot more regulatory pressure on trading and financial services firms, even tiny ones.

#### The Quantum Future is Almost Here

All of the above might sound futuristic, and so it is. But as I have pointed out, Google is already working with a quantum computer. We can be pretty sure that such computers will be widespread in just a few short years. And we can also be sure that the impact of these computers won't just be their awesome power and performance, even though they will have both.

The real impact of quantum computers is going to be the applications of these computers. In order to use them effectively we are going to have to think outside the box. In effect quantum computers are massively parallel computers that are able to do their calculations in dilated time – that is in no time at all. To use this power responsibly we are all going to have to think long, hard and very imaginatively.

The companies and governments that will win in this contest are going to be those that have figured out how to use these awesome powers in totally new areas to solve totally new problems in ways that benefit their peoples and companies without leading to social, political and economic divisions that make society worse off.

It won't be an option to ignore either quantum computers or their applications. To come back to HFT, quantum computers will be used also for HFT even if it's not in China so this problem is also

going to have to be addressed so that Chinese companies are not at a disadvantage compared to overseas companies.

Quantum computers are definitely progress and overall they are going to improve the human condition.

But that's not going to occur unless companies and governments give serious and imaginative thought to how to best use them.

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