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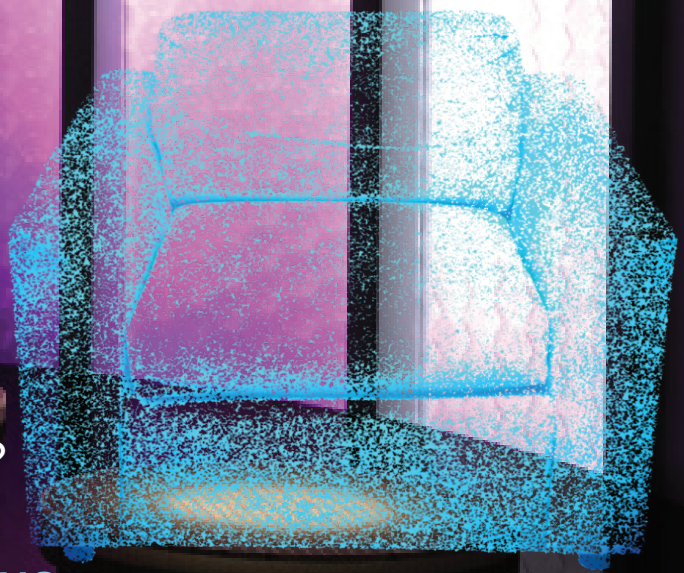
Macroscopic quantum teleportation



PSYCHOLOGY
Paranoia: destroying society?

QUANTUM SUPERPOSITIONS
Punxsutawney Phil

BIOPHOTONICS
Imaging shows protein folding Gangnam style

Factorizing large numbers made easy

by Kevin Smith

Two renowned scientists team up to develop a revolutionary technique to factorize large numbers. Their results will have profound impact on cryptography, number theory, and computer science.

Andre Geim and Peter Shor already sit at the top of their respective fields. Geim, from the University of Manchester, created the remarkable material of graphene using little more than some scotch tape and pencil lead. This discovery has revolutionized both condensed matter physics and the electronics industry, and earned him the Nobel Prize in 2010. Shor, a mathematician at MIT, sparked the field of quantum computing with his discovery of an efficient algorithm for factorizing large numbers. This is believed to be impossible using classical computing, and forms the basis for many cryptography standards.

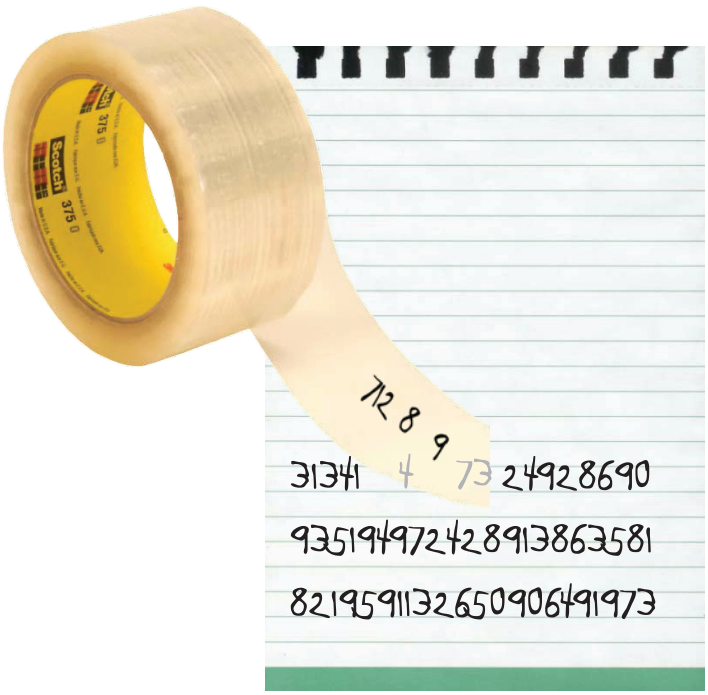
Now, as reported on p. 395 in this issue of *Nature Relocations*, they are at it again. They have found a new method of efficiently factorizing large numbers – using, you guessed it, scotch tape. "I have always been fascinated by this space-age sticky stuff," says Geim. "So when I heard Peter Shor give a talk about his algorithm, I thought to myself, what if scotch tape could take the place of the quantum Fourier transform and modular exponentiation steps in his algorithm?"

Over the past two years, Shor and Geim secretly teamed up to perfect this idea. The concept is illustrated in the photo below, which Shor describes in the following way. "First, you write down the really big number you want to factorize on a piece of clean paper. Then, you just start peeling away at the number with scotch tape. Some of the numbers peel off the page right away, it's always the last few numbers that are hardest. But with a bit of practice, the number is completely factorized after 3 or 4 tries. It's really brilliantly simple. I can't believe I wasted five years of my life learning quantum physics when all it took was a trip to the Office Max."

The national security implications of now being able to decipher many cryptographic protocols has many government and military officials on edge. There have been unconfirmed reports that American, Russian, and British military installations are now stockpiling vast reserves of 3M scotch and packing tape. In addition, the American government has passed a law banning the sales or transfer of scotch tape to Iran, North Korea, and Pakistan. Iranian President Mahmoud Ahmadinejad, however, has insisted that his country is only using scotch tape for peaceful purposes. "We have a fundamental right to wrap presents up and attach papers together. It is not fair to expect our citizens to only use staples."

Despite this controversy, the result of Geim and Shor is being lauded by physicists, mathematicians, and computer scientists as one of the greatest results of the past century.

Kevin Smith is a freelance science writer. He has contributed to prestigious magazines and journals including Nature, National Geographic, Golf Digest, and Maxim.



Experimental demonstration of the scotch tape factorization method developed by physicist Andre Geim and mathematician Peter Shor.

ARTICLES
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Macroscopic quantum teleportation

Darrick Chang[1] and Stephanie Wehner[2]

One of the most dramatic consequences of quantum physics is the ability to "teleport" the complete quantum state of a system from one location to another, in a manner that does not involve the physical transport of the system itself. This mechanism of "quantum teleportation" has been previously demonstrated for small systems such as few-photon optical states and individual atomic quantum bits. Thus far, however, the teleportation of a macroscopic system has remained an outstanding challenge. Here, we theoretically describe and experimentally demonstrate a novel technique to achieve teleportation of a macroscopic object. In particular, we have applied our technique, known as Kinetically Induced Concatenated Quantum ASSembly (KICQASS), to teleport the quantum state of a chair over a distance of 200 meters with a fidelity of 120 $\pm$1.7%. We expect that our results will have significant implications in areas ranging from quantum information processing to the stealthy retrieval of large-scale furniture.

Since the experimental demonstration of quantum teleportation of states of light over a decade ago, it has been a dream that similar techniques could one day be applied to teleport more complex states of matter. One of the major bottlenecks, however, has been the robust and high-bandwidth generation of entangled quantum bits, which constitute the fundamental building blocks for any teleportation protocol. Achieving the capability to teleport entire quantum systems at the macroscopic scale would have significant impact in areas such as quantum information processing and the investigation of the foundations of quantum mechanics.

In this Article, we report on a major breakthrough along these lines. Specifically, we have developed a novel technique, known as Kinetically Induced Concatenated Quantum ASSembly (KICQASS), which enables the rapid, parallel generation of entangled resources and their application to the teleportation of a macroscopic quantum state. As described below, this technique takes advantage of state-of-the-art developments in quantum error correction, optical levitation, deception, misappropriation, and market capitalization. We emphasize that our technique is quite robust, in that it can be performed under ambient conditions and requires only a moderate amount of espresso pods and a helpful secretary as ancillary resources. While our current technique thus far enables the quantum teleportation of systems up to several meters in size, we envision that a more advanced version of our protocol (KICQBIGASS, described in the Supplementary Information) will in the future allow for the teleportation of even more challenging systems, such as a sense of fashion to physics researchers or a set of brains to the Republican Party.

The system we have chosen to teleport consists of a green leather sofa chair. However, it should be pointed out that our techniques are completely general, and in particular, a chair of any other color or upholstered with any other natural fiber could have also been teleported with only a polynomial overhead in the resources required. As illustrated schematically in Fig. 1, the chair was initially prepared in state $|\psi\rangle$ by "John" in the Jorgensen Lab in 1998, using ancilla funding from the NSF. The chair was subsequently transported adiabatically to "Alice" in the Lauritsen Lab in 2009. Following this state preparation procedure, the KICQASS teleportation procedure was performed, wherein the entire quantum state of the chair was transferred back to John in Annenberg, thus spanning a physical distance of nearly 200 meters. Our technique is capable of achieving quantum teleportation over greater distances, and the distance employed in the present experiment was chosen primarily for convenience (*i.e.*, subsequent usage of state $|\psi\rangle$ by John). Following a straightforward state purification procedure (Clorox) the teleported state $|\psi'\rangle$ was verified in a non-destructive manner by John, where it was determined that the original state was reconstructed with a fidelity of 120 $\pm$ 1.7%. Remarkably, the high fidelity indicates that the properties of the final state even exceeded the initial state. The experimental details involved in implementing this protocol, as well as its theoretical basis, are presented in more detail in the next section.

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LET'S SEE WHAT
ACTUALLY HAPPENED...

~~TELEPORTATION~~ OF ~~MACROSCOPIC~~ OBJECTS

DARRICK CHANG AND STEPHANIE WEHNER

HEIST

AT LAST! OUR SHINY NEW BUILDING WAS READY...

... FILLED WITH THE LATEST DESIGNER FURNITURE..

... AND AN ALL NEW ROOM FOR THE GROUP MEETING..

TWO WEEKS AGO I WENT TO QIP...

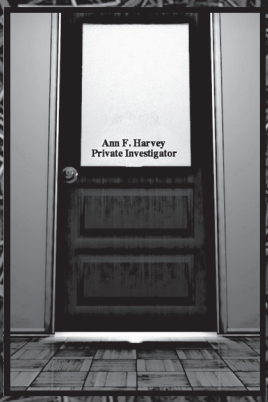
.. AND AFTERWARDS I PROVED THAT P != NP !! ... JOHN?...

... OR WAS IT?

.. ALL WAS WELL WITH IQI...

THE CHAIR! CLEARLY IT HAD TO BE RETURNED.

PROFESSIONAL HELP WAS NEEDED...



BUT WHERE COULD IT BE?

NOT IN ANNENBERG, NOT IN JORGENSEN... IT WAS NOWHERE TO BE FOUND!

THE CHAIR WAS EVENTUALLY LOCATED IN LAURITSEN, ALL THE WAY ACROSS CAMPUS...

... HIDDEN DEEP INSIDE A FORGOTTEN COFFEE LOUNGE ALONG WITH IQI'S OTHER OLD FURNITURE.

?!!

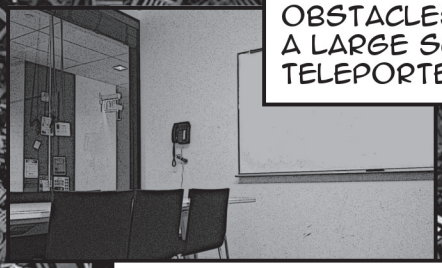
THE DECISION TO RECOVER THE CHAIR WAS MADE QUICKLY...

... BUT THE DISTANCE WAS LONG AND THE CHAIR WELL GUARDED...

..CAMPUS SECURITY...

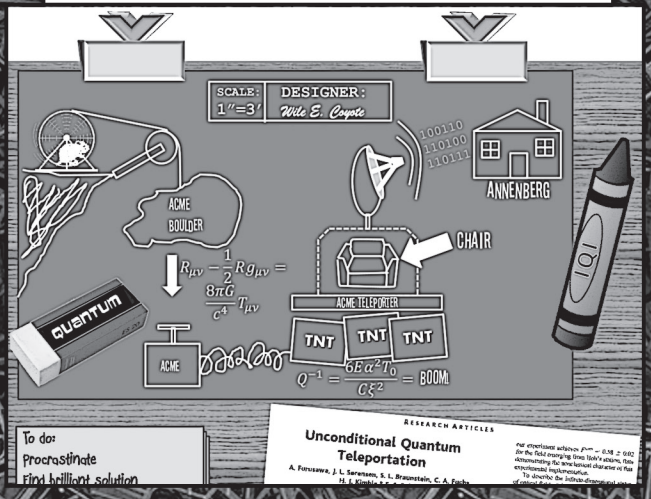
..AND RABID BEAVERS!

..CANNONS..



BY FAR THE EASIEST WAY TO OVERCOME THESE OBSTACLES WOULD BE A LARGE SCALE QUANTUM TELEPORTER!

CAREFUL PLANS WERE DRAWN UP...



..UNITIL FINALLY ONE QUIET NIGHT...

... SNEAKING TO LAURITSEN...

... THE TIME CAME TO INSTALL THE FIRST EVER MACROSCOPIC QUANTUM TELEPORTER.

A FREIGHT LIFT WAS CONVERTED....

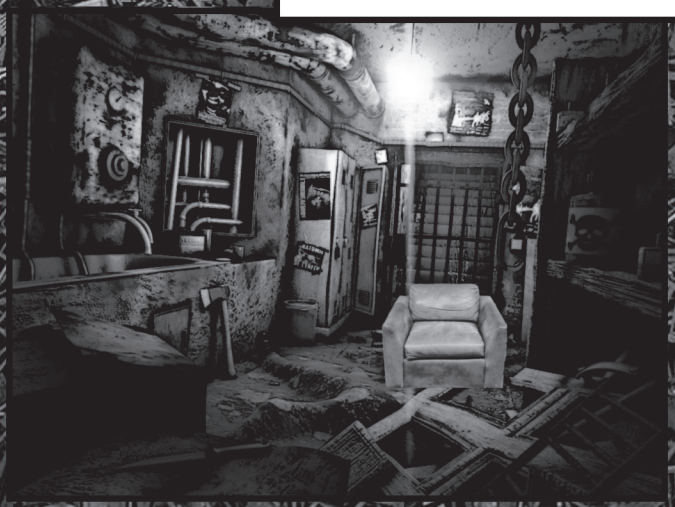
...INTO THE QUANTUM TELEPORTER'S PLATFORM.

IT WAS PRIMITIVE BUT GOOD ENOUGH FOR ONE TELEPORT...

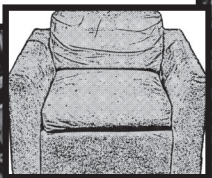
ON THEY WENT...

..TO TRACK DOWN THE CHAIR.

IN THE LAST CORRIDOR, DOWN THE LAST STAIRS, IN THE VERY LAST ROOM...



BY ALL APPEARANCES NOT A DAY LATE..



GLOOP GLOOP

NOO!!!! STOP!!

WHRRR

IT WAS ON THE WAY TO THE TELEPORTER WHEN SUDDENLY...

WHRRR

WHRRRR

SOMEONE WAS ALREADY USING THE TELEPORTER!

IT HAD DEFINITELY WORKED...

...ONCE!

WHAT NOW ?!?

TOO LATE.....

THREE HOURS TILL SUNRISE...

... TIME ENOUGH TO TEST PLAN B VIA A SIMULATION...

WOPR

ERATION PLAN RESPONSE

Caltech General Store
Pasadena, California
April 1, 2009

1.	Oxen	$360.00
2.	Wagon	$420.00
3.	Food	$190.00
4.	PhD student dime/dozen	

Total bill: $970.00

NSF money left: $45.00

Press SPACE BAR to leave store

You can buy whatever you need at Matt's General Store.

Press SPACE BAR to continue

Congratulations! You have made it to Annenberg.

Annenberg
April 8, 2009

Press SPACE BAR to continue

STEPHANIE has a broken pencil.
Lose two days.

Press RETURN to size up the situation

Date: April 2, 2009
Weather: good
Health: good
Next landmark: 200 feet

Press SPACE BAR to continue

Caltech river crossing
April 5, 2009

Weather: cool
River width: 100 feet
River depth: 2.3 feet

You may:
1. attempt to ford the river
2. caulk wagon and float it across
3. call Ann for help

What is your choice? 1

Caltech security

You have stolen a chair.

Press RETURN to size up the situation

Date: April 4, 2009
Weather: good
Morals: questionable
Next landmark: 300 feet

Press SPACE BAR to continue

Coffee is running low.

Press RETURN to size up the situation

Date: June 22, 1848
Weather: hot
Health: good
Food: 595 pounds
Next landmark: 142 miles
Miles traveled: 688 miles

Press SPACE BAR to continue

A WAGON ?!?
A QUANTUM SIMULATION
MIGHT HAVE BEEN BETTER...

..PAST MILLIKAN..

...ACROSS THE BEAVER DAM...

?!?

NEARLY THERE...

WITH THE CHAIR RETURNED...

... ALL WAS WELL WITH
IQI AT LAST..

THE END

HAPPY 60TH
BIRTHDAY!!

TO BE CONTINUED....

Physicist John Preskill turns 60

Quantum information theorist at Caltech is widely regarded for his own contributions and his support of young researchers in the field. *Nature Relocations* has asked his former students, postdocs, and colleagues to provide their thoughts to mark this special occasion.

Dear John,

I get asked a lot about what it was like to be at Caltech. I guess the name "Caltech" transcends the world of science and research. People have a curiosity about the home of Richard Feynman, of JPL, of the characters in the Big Bang Theory, and of the most losing basketball team in the world. But the question that people ask has an easy answer, and one that I never tire of telling. Caltech is truly a special place, and the three years I spent as a postdoc in the IQI have been by far the best experience of my professional career.

I've actually never asked you what your vision was when you set up the IQI, but whatever it was, it works beautifully. I can honestly say that I never had a bad day in my three years there. To me, the IQI was a place that I was excited to go to each day, to learn, talk about, or try and figure out something new. To throw around crazy ideas and see what sticks. Heck, even to go and dabble in experiments, to see if your idea might actually work. And best of all, to be around a bunch of people who are completely gung-ho about doing science. I think that everyone fed off of your curiosity about all things unknown – it showed up in the lunchtime conversations and group meetings and everything in between. To be in a place where scientific curiosity was the first, last, and only thing that mattered was truly special.

And beyond any of the actual research that I did, that environment at the IQI is the most lasting memory of my time there. At the risk of sounding cheesy, every day it serves as inspiration of why and how I want to do science. So, John, thank you – I am eternally grateful for that. Happy 60th birthday!

With best regards,
Darrick

Dear John,

It is very difficult to express in writing how much I enjoyed my time at IQI or how grateful I am to you for making it all possible. Your great influence on me personally, however, is not limited to IQI itself even though I don't think I ever mentioned this to you. Almost ten years ago in 2003, you gave a university colloquium in Leiden in the Netherlands. At that time I was still an undergrad in Amsterdam, but as I was very curious about quantum information I had gone to Leiden to see your talk. I am sure you don't remember me from Leiden, as I was much too terrified to talk to anyone there at all.

Nevertheless, your talk itself had a great effect on me as it was my first encounter with quantum error correction, and showed me that quantum computing was not just about algorithms - but rather that my prior notions about classical error correction and information theory were completely inadequate and quantum information was fundamentally different. If it hadn't been for your inspiring talk, I might have missed this beautiful subject and gone on to do something rather different.

Some time after my first visit to IQI, you offered me a place in your group. I remember I was actually at my computer just when your email arrived and I almost replied to you within the span of about a minute. Almost, because I had this strange idea - quite bizarre in retrospect - that I should maybe control my excitement and pretend to think about this, and so I waited nearly three days to tell you that I would be most happy to come. However, it would be a stretch to say that it took me even one minute to decide. In fact, I should confess that I was so much hoping to join IQI that I had not even applied anywhere else at that point, simply because I was still trying, and failing, to identify a place that would even remotely compare.

Needless to say Caltech itself was a very special place, and as a whole offered me a glimpse of very diverse and intriguing research. I have never felt so at ease - so comfortable and relaxed anywhere else. Caltech itself, however, is not what made IQI special. That was entirely your doing, and I'm sure IQI would have been equally fantastic anywhere else. You created a great place for us to discuss, do research, travel, host our own visitors and even hold workshops. You allowed us to be entirely free in pursuing our own passions, but at the same time showed keen interest and concern in whatever we were doing and always had an open mind. You devoted your time to keep up with all the diverse strands of research at IQI, where you could switch from one topic to the next with seemingly no effort at all. For all of this, and more, I am deeply grateful.

I am attaching two snippets from my time at IQI. On a personal level, my stay was great fun, and one of the things you may remember is the retrieval of your lounge chair after our move to Annenberg. In case you're wondering how it actually made its way to Annenberg, Darrick and I are now prepared to reveal the true story. I also very much enjoyed my time scientifically. I am sure somewhere in your records about the group meeting you will find vague claims by myself that one could use quantum techniques to prove convergence of SDP hierarchies for polynomial optimization. It took some time, but Andrew and I have now finally completed our article! We are attaching it because it draws on ideas starting with Andrew's work on testing separability done during his own stay at IQI nearly a decade ago, all the way up to ideas developed during my own stay and afterwards. For me personally, it represents one of the things that I enjoyed most about IQI namely that ideas from very different areas, be it physics, computer science - in fact any strand of quantum information - have the opportunity to interact at IQI to find a very new approach. Again, many thanks for making this all possible.

With this, I wish you a very happy 60th birthday!

Warm regards,
Stephanie

Dear John,

It is amazing to reflect on my time at Caltech and to realise that it is nearly ten years since I left. The intellectual environment there is something that I have missed ever since, and in particular the group you led which became the IQI. The impact that the IQI and your scientific and intellectual leadership has had on quantum information is truly impressive. Importantly for me though, my entire research program now has arisen very directly from the things I learnt during my time at Caltech and as part of the IQI. I was a very ignorant student from a distant province when I first arrived and I am incredibly grateful for the opportunities you and others at Caltech gave me.

For this reason I am particularly happy that Stephanie and I can include our recent paper in this booklet. Although it has no physics really, it grows very directly from work I did with Federico Spedalieri and Pablo Parrilo when I was at Caltech and it reflects the unexpected interactions and genuinely interdisciplinary work that goes on there.

Your example as a group leader is one that many of us who are alumni of the IQI have tried to emulate in our later careers. I think many of us particularly remember the Preskill group meetings and the weekly ritual of reporting what we had been doing that week, the subsequent whiteboard talk, and your searching questions from the floor throughout. Although the components are familiar, your meetings have a special flavour that seems to have influenced many groups in our field where alumni of the IQI regard the Preskill group meeting as a gold standard. I know at Sydney that when Stephen Bartlett and I discuss what is working and not working in our group, we constantly refer to how things are done at the IQI.

However, one aspect of the meetings that I do recall as causing occasional grumbling was the fact that after the group increased in size meetings had been known to exceed three hours! On one occasion when the meeting room in Jorgenson was particularly packed matters came to a head and it was decided to draw lots to divide the group in two so only half would report on their week's work. A Canadian coin was at hand and the group was to be divided into "Queens" and "Bears" to match the two sides of the coin. As it happened the natural dividing line down the middle of the room ran straight through me and you needed to adjudicate which side I should be deemed to be on. You looked thoughtful for a minute and remarked, quite seriously but perhaps with a gleam in your eye, that in seeing me around campus you had always thought that I seemed more a queen than a bear. And so that was that!

It is this sort of careful and considered judgment that has led to your great success in research, in building a group and in inspiring others in your research field!

Have a very happy 60th birthday!

Warm regards,
Andrew

$10,000 REWARD

Rogue quantum physicist WANTED: Dead and alive

Ex-Caltech quantum physicist David Jones is charged with three counts of transferring restricted nuclear spin material to a hostile foreign country, and two counts of divulging classified Chern numbers to a foreign operative. He is considered armed and dangerous, and will not hesitate to use his laser pointer if confronted. Persons with knowledge of his whereabouts are encouraged to contact the FBI Crime Division at 1-800-348-3482. Information leading to his arrest might lead to a reward of up to $10,000.

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