# Ion Guiding: New Applications for tiny apparatuses

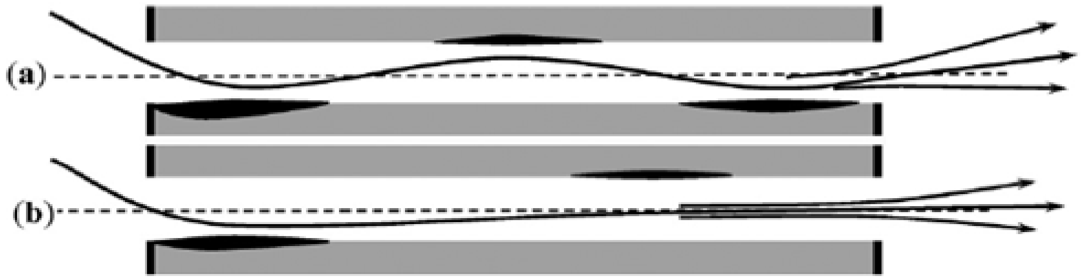


Figure above shows trajectories using ion guiding – a process done by inserting ions within capillaries to guide a beam of an ions following. (a) and (b) are two typical trajectories occurring within capillaries. Capillaries are gray and black regions are where charge patches occur.

A new application, done by shooting beams of ions within nanocapillaries of polyethylene terephthalate and polycarbonate insulators and having them exit with the same charge as upon entering. This is done by exploring charge patches and altering angles of incidence to

Doctor Nikolaus Stolterfoht created the interesting article on ion beam guiding and explored the effects of changing different parameters. He worked on the article at Helmholtz-Zentrum Berlin fur Materialien und Energie and continued his research in other laboratories from Japan, England, Netherlands, and Hungary. Being very fond of fundamental physics he was attracted to a few fields which eventually led him to nanotechnology and inventing ion guiding through nanocapillaries. He became very interested in his invention and eventually did a few studies on ion guiding and its effects.

The research in nanotechnology is important because it is beginning to lead the way in many other areas of science including health. Research in nanotechnology led Dr. Stolterfoht to ion guiding and "apart from the challenge to understand self-organizing mechanisms (which do not happen often in physics) there are applications for these nanocapillaries. For instance, a multitude of these tubes can be used as filters to separate very small particles". (Stoltenfoht, 2013). This research he has performed will become very beneficial in the near future. To conclude, he used very small tubes with a diameter 10000 times smaller than a millimeter and sent highly charged ions through these tubes to experiment with the chemical and physical properties of the inner capillary surface and how the ion would travel through it.

This tests he performed did not get the results as expected, which although it did not meet expectations, it was more beneficial this way. Since ions are shot into thin capillaries, it might be expected that they would lose their charge to the inside surface. However, the charge remains on the ion and, depending on a few parameters (e.g. angle of incidence, intensity, or diameter of beam) the particle may be able to leave the capillary with the same excess charge as upon entering. When these parameters are altered with, the ion beam may not enter the capillary or run into the capillary walls and may begin to accumulate into what are known as charge patches. These charge patches are built up ions that stay along the side of the capillary. If enough ions collect in a particular region, a charge patch is created and can deflect the following ions.

Ion guiding was done by testing two different types of material: a polyethylene terephthalate (PET) and polycarbonate (PC). Both materials are insulating materials, which is important in this experiment. (If they were conductors, the ions would definitely lose their charge. This would then just make the ions flow through the conductor regardless of their effects of excess charge from ions). The charge patches as mentioned previously are an accumulation of ions held together in certain regions within the capillaries where if enough accumulate, can affect the rest of the ions following. There were several experiments done to test the most efficient way to transport the charges from entrance to exit. Changing the tilt angle of the capillary with a mean guiding angle of 5.6$^{o}$ and the amount of charge of particular charge patches came with results that would cause the ions to deflect and potentially not be able to reach the capillary exit – these consisted of overcharging the charge patches. If there were no charge patches, no ions would be able to escape the capillary because there needs to be some deflection within capillary. If there was not enough or too much, the ions within the beam would get stuck to the capillary surface. Another experiment was performed on the transport of deposited charges so that the ions shot into the capillary would eventually leave by depositing ions in the capillary beforehand. Particles were found to be weakened more by charge flow along the capillary walls than shooting ions through the capillary. This was a big discovery, considering it was previously believed that if an ion hit the capillary wall, it was assumed to deposit its total charge as a cluster of holes in one location and go from being an ion to its neutral form – a neutral atom.

This research can lead to many future applications. Now that research has been done on transporting a current, through a capillary more applications can be explored with the use of capillaries and charge. Dr. Stolterfoht, suggested this work will be directly relevant to two existing applications, and both relevant to the field of healthcare. The first is for vaccinations, where micro-sized glass particles can be filtered from injectable medicines (from being stored in glass bottles). These filters made from nanocapillaries can separate glass particles from the liquid and prevent them from entering the patient's body. This can be very beneficial for any patient taking any vaccines via injection. Another future suggestion by Dr. Solterfoht would be to use nanocapillaries to produce very narrow beams of ions (the beams would be from what leaves the capillary) and then sent to individual living cells or in different parts of a cell. This would be very beneficial to targeting cells in the body considering everything would be so miniscule. This could potentially lead to detecting cancer by helping targeting certain cells – which would make it easier to dispose of them.

**Interview with Dr. Stolterfoht:**

[We both said hello but unfortunately our microphones cut out immediately after. I decided to instant message him instead to continue with the interview.]

J. Bayliss: Why is this research so important right now?

N. Stolterfoht: Oh I thought that everybody agrees that nanotechnology is a hot subject. The processes I am studying are concerned with self-organizing processes which are of high interest for theoreticians.

J. Bayliss: I agree that it is definitely a hot subject right now. Is there anything you were aiming for specifically out of your research?

N Stolterfoht: Yes, capillaries are very small tubes with a diameter 10000 times smaller than a mm. No one can look into such tube. Therefore our aim is to send highly charged ions through these tubes to learn some chemical and physical properties of the inner capillary surface

J. Bayliss: So what would you say was the significance in shooting ions through the insulator? Did you want to see an effect (if at all) from the PET or PC? Also, did you expect to get the results you got?

N. Stolterfoht: When we started the experiments we did not expect to find the present results. The results we expected were that the ions are changed into neutralized atoms, since the interaction with the surface generally neutralizes the ions. The fact that ions emerged from the capillary was big surprise.

J. Bayliss: For your research you said that the ions emerged, even though you did not expect that. Is that beneficial to your research that ions came out instead of what you had thought?

N. Stolterfoht: Yes it is beneficial. The ions are kind of a probe that tell you about the inner properties of the nanocapillary. When the ions remain in the tube or are neutralized they cannot tell you so much. But overall, the surprise had to be explained and that brings me back to the self-organizing mechanism that allows ions emerging from the capillary.

J. Bayliss: Ah, this makes more sense. Why did you choose to perform research on this experiment? Will you continue?

N. Stolterfoht: Yes, after the experiments I performed more theory (see the last two Papers) to understand the self-organizing process. It is concerned with a deposition of charges on the surface that produces a repelling field which inhibits the ion touching the surface so that they can emerge the capillary without charge exchange. This is a challenge for theorist to model the mechanisms. Apart from the challenge to understand self-organizing mechanisms (which do not happen often in physics) there are applications for these nanocapillaries, for instance a multitude of these tubes can be used as filters to separate very small particles.

J. Bayliss: would that be more difficult to experiment with? Also, as a generalization, what are the next steps in the research or what applications the research might be good for in the long run?

N. Stolterfoht: To you last question two examples: Imagine a liquid medicine for vaccination. Often these liquids contain small micro sized glass particles; such filters of nanocapillaries can separate these glass particles, which are not very healthy to enter a body.
Second: There are already applications to use nanocapillaries to produce very narrow beams of ions (emerging from the capillary) which can be sent into individual living cells or even in different parts of a cell. Such apparatus does already exist in a Japanese laboratory, where I stay from time to time.

J. Bayliss: Wow! That sounds really exciting! So then what area of physics do you enjoy the most?

N. Stolterfoht: I changed fields all 7 years but I used always energetic ions to learn some fundamental physics. I started with atomic collision physics, went to surface physics and ended at nanotechnology. I enjoy very much the ion guiding in capillaries as I invented the effect.

J. Bayliss: You invented ion guiding?

N. Stolterfoht: Yes this is the name of the physics we are talking about and I invented it in 2002 published in Phys. Rev. Lett.

J. Bayliss: Oh that's really interesting! Where did you perform the experiments? (I'm assuming Helmholtz-Zentrum Berlin fur Materialien und Energie?)

N. Stolterfoht: Yes, I started the work there (my home laboratory) but it continues in Japan, England, Netherlands and Hungary.

J. Bayliss: That's really cool! (I've finished my questions for the interview - if I do have any others I'll email you. I don't think I will have much) Thank you very much for your time! I really appreciated it! If you want, I can send you a copy of my review.

N. Stolterfoht: Alright, please send the summary. I wish you the best for your exams.

J. Bayliss: Thanks again and take care!