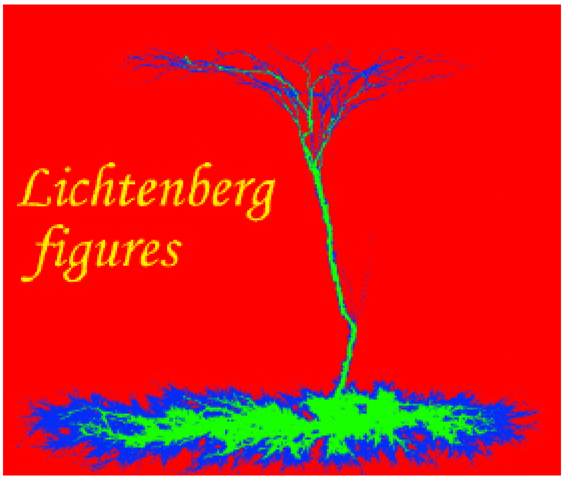
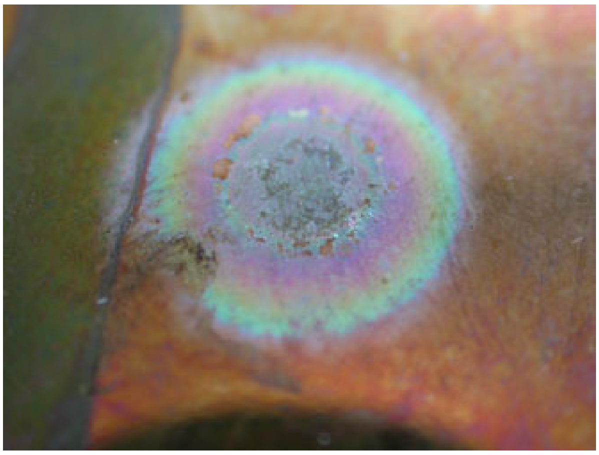


are named after the German physicist Georg Christoph Lichtenberg. One possibility to create such figures is to irradiate acrylic with a beam of high energy electrons. As the charge builds within the insulator, the effective voltage can reach millions of volts. Finally the electrical stress exceeds the dielectric strength of the plastic, causing it to suddenly become conductive in a process called dielectric breakdown.

Acrylic is easy to get hold of - but a high energy electron beam? This is when being a medical physicist is definitely an advantage - at least if one is working in radiation therapy: we all use high energy electrons from a linear accelerator to treat patients, either directly, or to produce x-rays for treatment. If you are in this lucky situation, you should not rush to repeat our experiments, however: the dose rate available in clinical mode is insufficient to build up a sufficient charge within a short enough time; not all linear accelerators on the market are suitable for this exercise - and the suitable ones need to be modified. You must not try to repeat our experiments with a linac due to treat patients the next day - unless you have a large number of expensive spare parts sitting on your shelves.

Why?



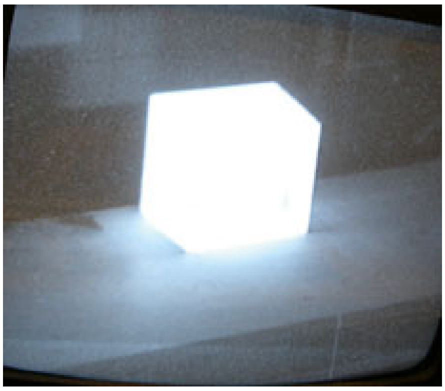
Look at the effect of the light field mirror (left) and the monitor chamber (right) to know why. The effect on the electronics was less easy to document - but similarly impressive! The next time you decommission your Varian Clinac 2100 (I cannot comment on other manufacturers' linacs), however, this is your chance.

UNDER NO CIRCUMSTANCES SHOULD YOU REPEAT THE PROCEDURE DESCRIBED BELOW ON A LINEAR ACCELERATOR WHICH IS STILL IN CLINICAL USE !

In the electron mode at maximum rep rate irradiation times of approximately 20 min are required to build up the necessary charge in the acrylic. In photon mode (6 MV) with the target removed, however, only some 6 to 10 seconds were needed during our experiment:

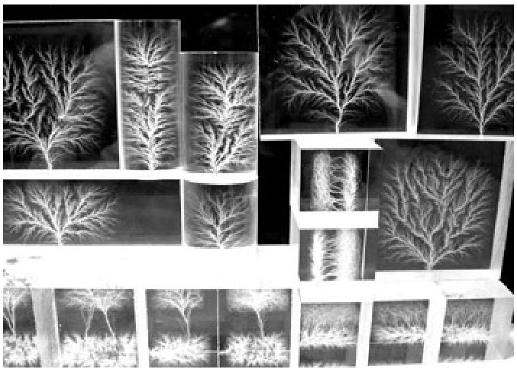
- As the acrylic block will later be placed on the treatment couch, rotate the gantry to lateral (90 or 270 degree, depending on the camera position for watching the event).

- The linac needs to be tuned in this exact position. As the monitor chamber will not deliver correct signals under these circumstances, and it will be damaged soon after the start of the irradiation anyway (see above picture) all steering servos are switched off (PFN and AFC servos stay on). It is therefore very important that the linac remains stable with the steering servos switched off.
- Now (with the beam switched off) the target is pulled out of the beam path, and fixed.
- Also the flattening filter is removed (as it would otherwise act as target).
- The acrylic is placed on the table on some wood (for additional insulation). At this stage the cross hair can still be used: mark the position of the block, and possibly note different table positions for blocks of differing sizes, as the light field mirror will also be destroyed pretty soon after the start of the irradiation; the lateral laser would also be useful for positioning - but if you want to keep using it, it might be a good idea to remove it first.
- Zoom in the TV camera on the acrylic, and switch off the lights before switching the beam on.

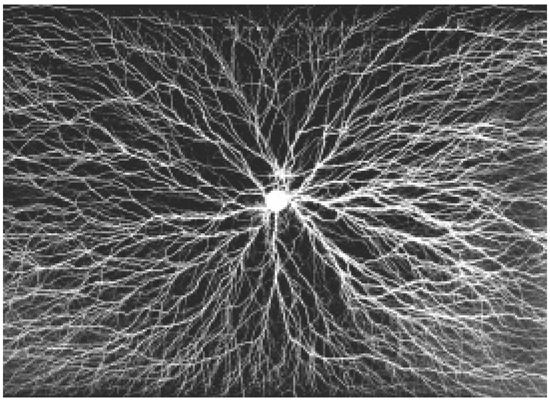


- One has to work in the service mode, to override the dosimetry and target interlocks.
- CAUTION: Due to the extreme dose rate not only the monitor chamber, but also the vacuum window might be damaged if the beam is switched on after these modifications!
- Watch the acrylic glow when the beam is switched on.
- The result is difficult to predict - find out by trial and error what you like best. Parameters are the block dimensions, holes drilled into the block, and beam-on time (a few comments are added below).
- In our experience it is not necessary (well ... not possible) to invoke the discharge using an earthed pin or similar object: even if the beam was switched off before the discharge occured "automatically", the discharge had occured by the time we were in the room.
- CAUTION: Even after discharge there will be residual charges on or within the acrylic! Before touching the block with your fingers, use an earthed cable on a long stick to remove at least the major part of this residual charge ... and don't be surprised to experience a prickly sensation nevertheless.

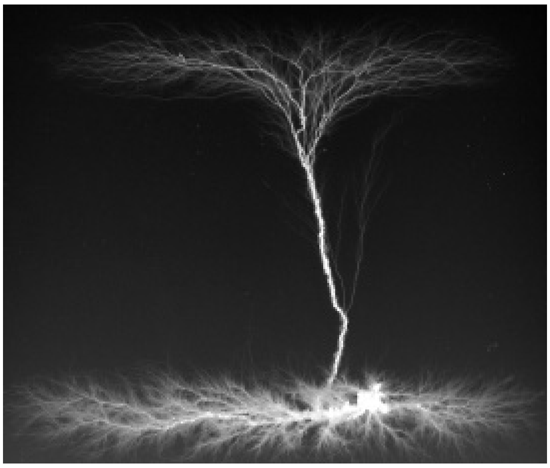
Seen below is the result of a long evening (the Clinac stood up to this extreme torture much longer than expected).



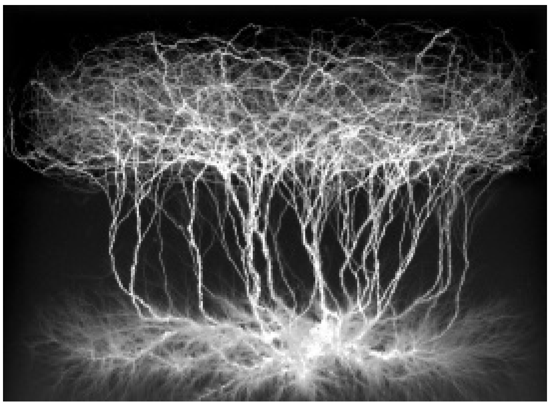
Block 10 x 10 x 3 cm^3
6 MeV electrons have a range of about 1.5 cm in Perspex; a 3 cm thick block is therefore ideal to get a Lichtenberg figure roughly in the middle of the block; a small hole (1.5 mm^{dia} and about 1 mm deep) was drilled in the centre of a side to provoke a discharge to this point. The hole not only defines the position, it also results in a discharge at lower charge, creating less damage to the acrylic, and producing a finer structure of the Lichtenberg figure.



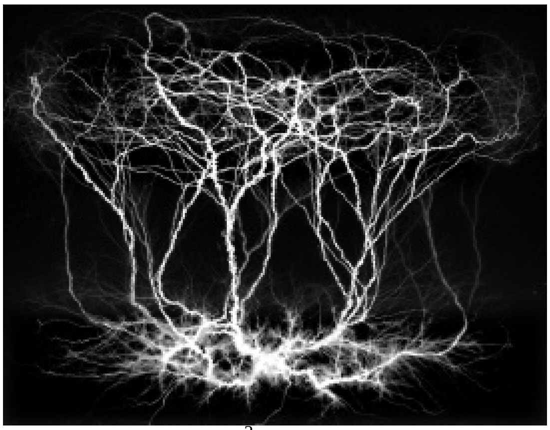
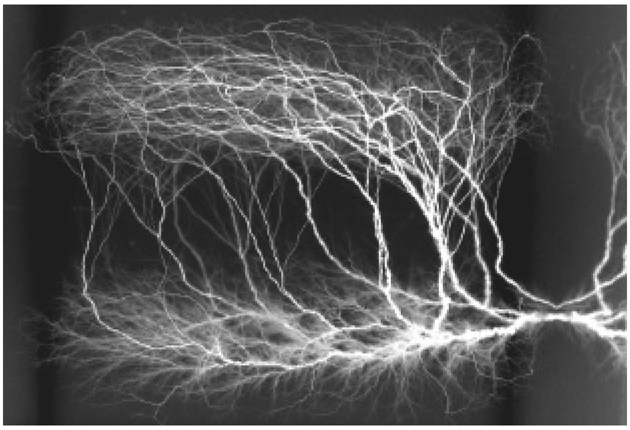
Block 5 x 13 x 3 cm^3
Hole drilled in the centre of the large side (white dot on the photograph); irradiated from the opposite side.



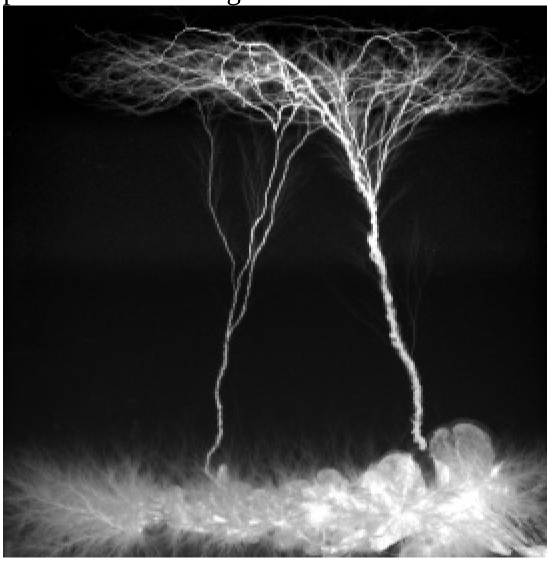
Block 7 x 7 x 5 cm^3
Irradiation from two sides. First irradiation from the "bottom" (on the photograph) with no hole drilled. The result of the first irradiation looked similar to the first photograph. with an arbitrary focus point sideways (= bright spot on the photograph). For the second irradiation the block was rotated, with the discharge being attracted by the damage in the acrylic caused by the first discharge.
This is the original photograph used for the "title picture" above.



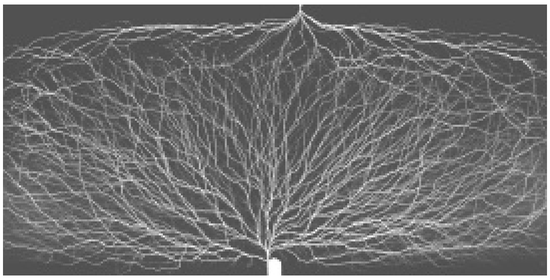
Block 5 x 5 x 5 cm^3
For the second irradiation (from the "top" of the photograph) irradiation was continued after the first spark, resulting in many fine lines due to almost continuous discharges between the paths of the original discharge. Not visible on the photograph is a strong yellow tint on the beam entry side of the second exposure, identical to what is usually seen on long used acrylic shielding block trays in radiotherapy.

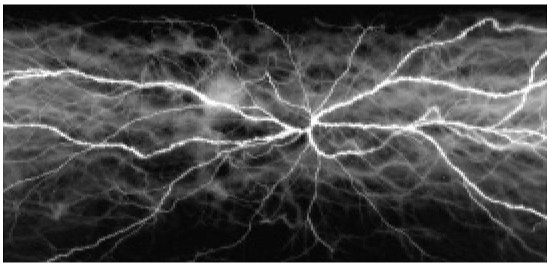
Block 5 x 5 x 5 cm^3: Irradiation as above; viewed from two sides. Whilst the first irradiation (from "bottom") discharges to a side, the second irradiation (from "top") always discharges to the existing paths created during the first irradiation.



Block 7 x 7 x 5 cm^3
First irradiation (from "bottom" of photograph) with a comparably high dose (for some reason the discharge occured later than usual) resulting in some severe damage (lower right corner of photograph); the second irradiation resulted in two simultaneous discharges along different paths.



Block 5 x 13 x 3 cm^3
Deeper hole (about 5 mm) drilled on one side; despite this a second simultaneous discharge to a second focus point on the opposite side occured.



Block 5 x 13 x 3 cm^3
Same block as above, viewed from the side.

Disclaimer: The fact that it worked for us is no guarantee that it will work somewhere else under different circumstances. Whatever you do, including taking any precautions considered necessary, it is entirely your responsibility.

Markus Arn, Wolf Seelentag (St.Gallen)

PS: Images can be downloaded for personal use from http://www.sgsmp.ch/lichtenberg.htm.