

Replicating the IMAGINARY collection of math objects using low-cost 3D printers

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The Abdus Salam
**International Centre
for Theoretical Physics**
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Why low-cost 3D printers?

- The IMAGINARY collection has been designed for production with professional 3D printers:
 - We estimated the total cost of the collection on the order of some hundreds of \$ (if printed in-house), up to some thousands (if printed by 3rd party service)
- So why don't try with our low-cost FDM printers?

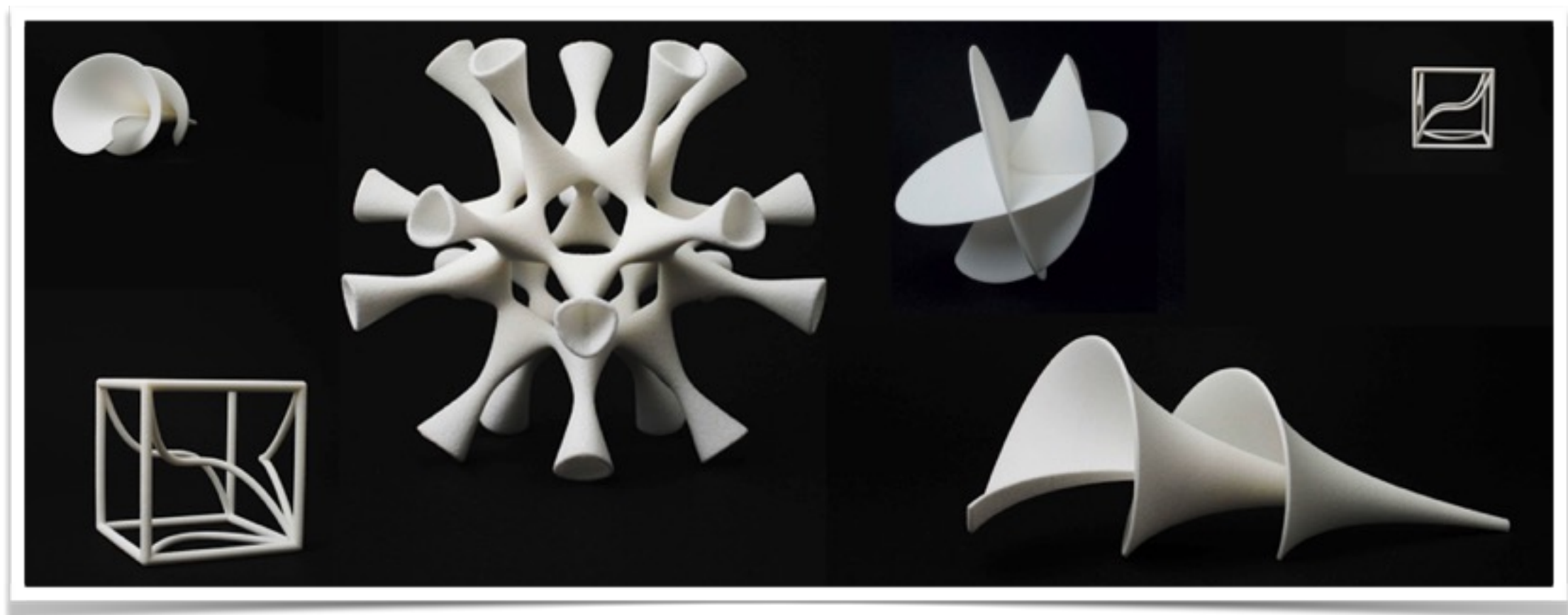
Issues to solve

Format of 3D models:

- acceptable formats for us are limited to .STL and .OBJ, but some model of the collection are in a different format (.X3D)

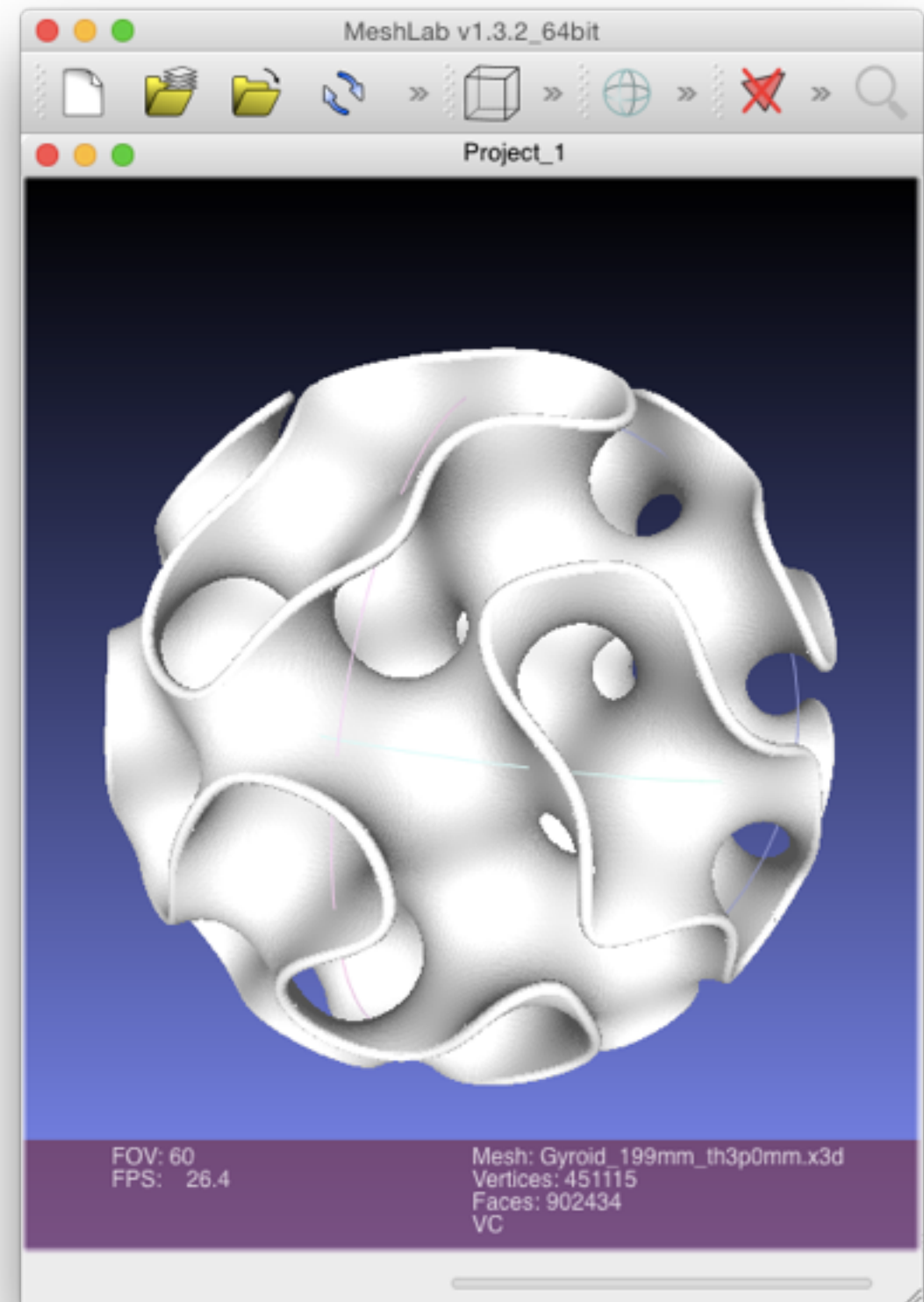
Geometry of 3D models:

- most models have been created for the purpose of SLS printing, so they are difficult/impossible to print with FDM printers



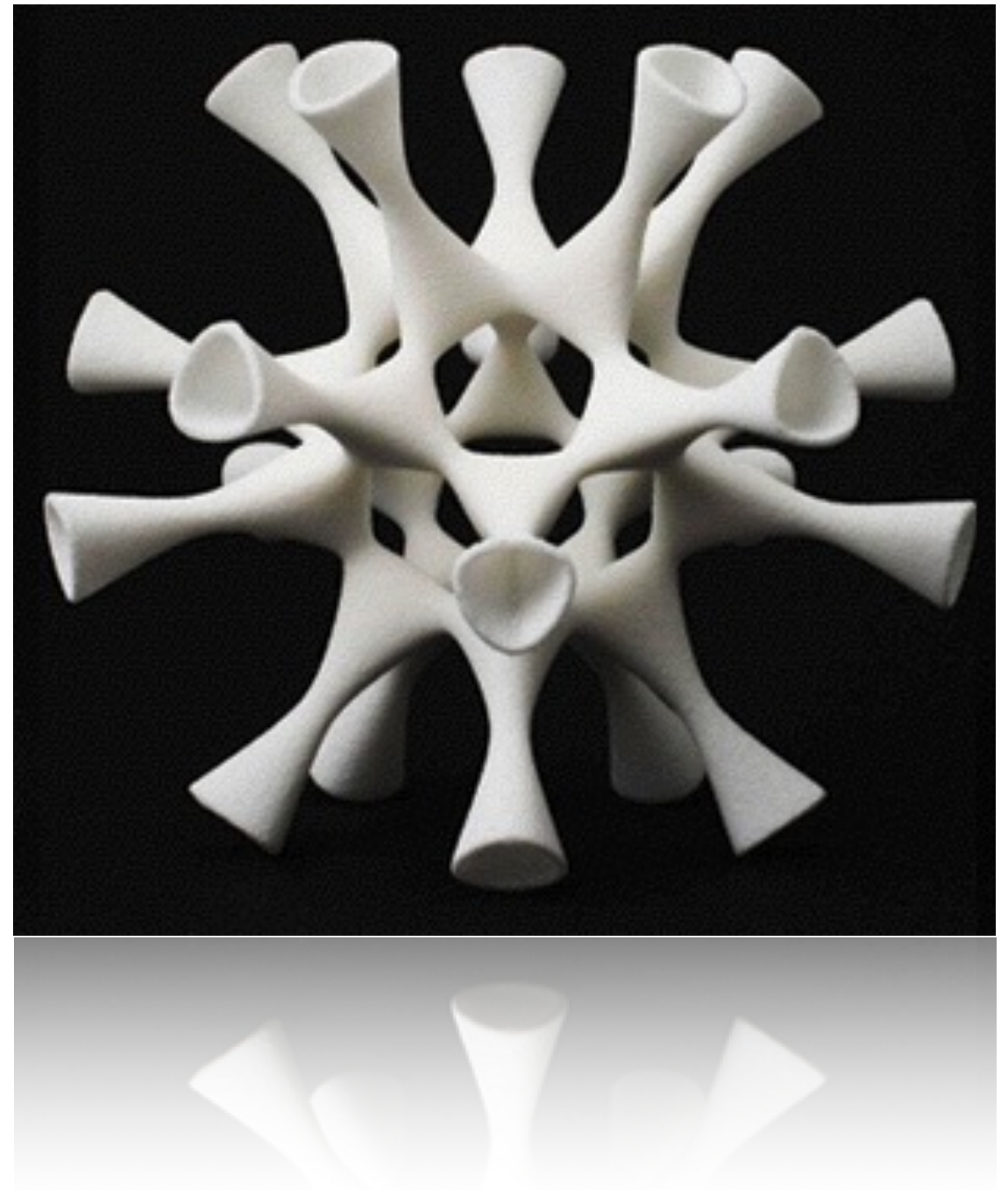
Format issues

- We had to convert some files from .X3D to .STL
- We used both Netfabb Basic (free version of a commercial software, with registration) and Meshlab (free opensource)
- This issue was easily solved



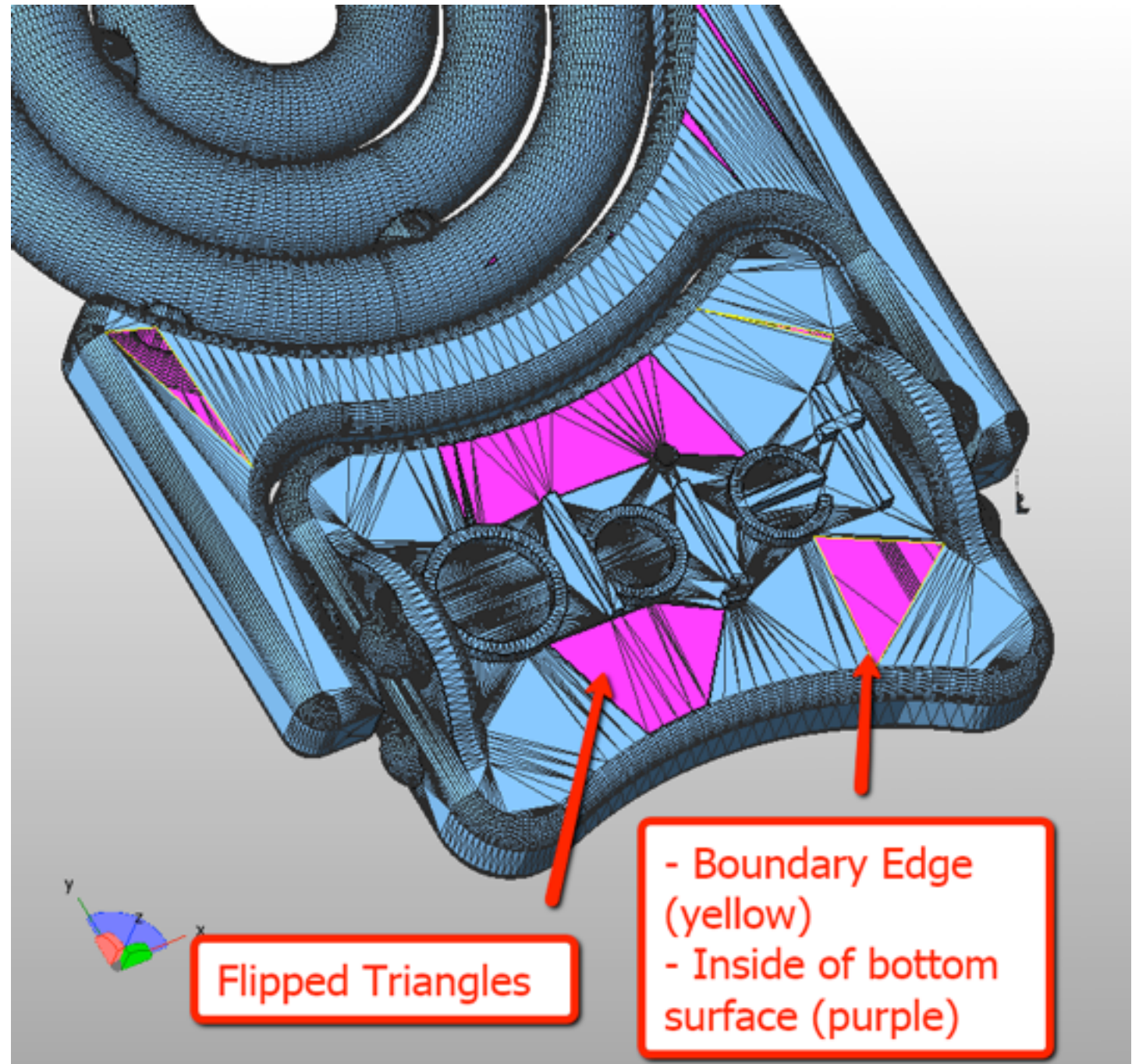
Geometry issues

- SLS printing technology has less limitations for the printable shapes than FDM printers, there is zero or little need of supporting structures, extreme overhangs are possible, etc...
- These are rather difficult problems to solve...

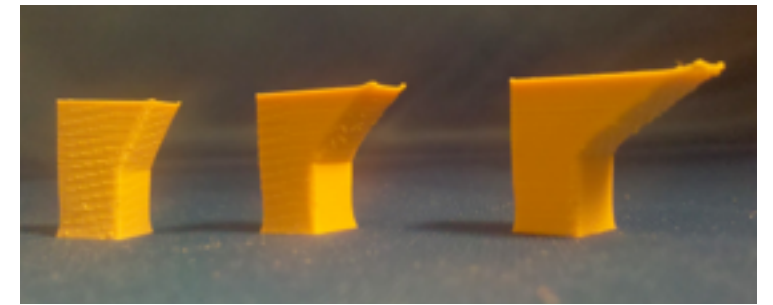


Repair a corrupted/malformed STL file

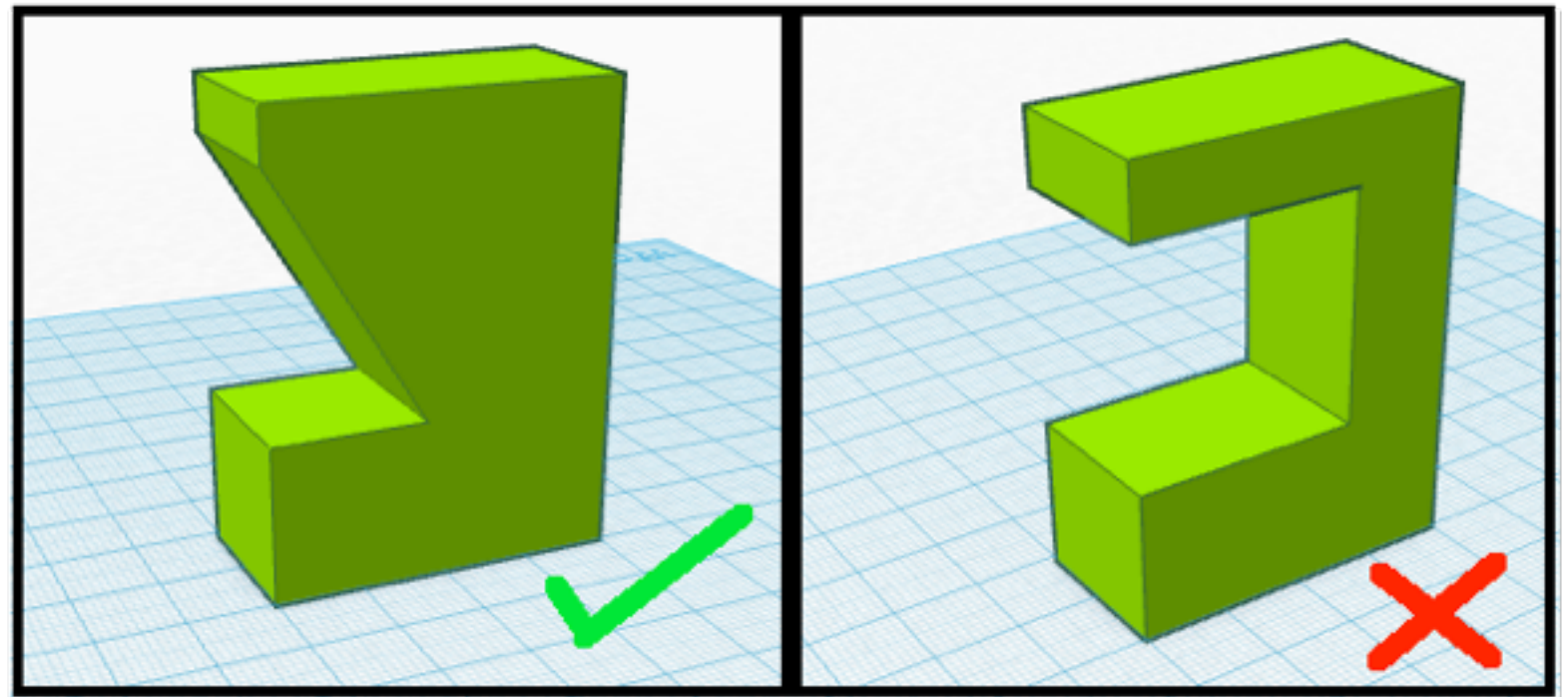
- A 3D model should be a **manifold** and should have a "***watertight***" mesh, in order for the 3D printer to be able to identify correctly the inner and outer volume of the object. This means, in practical terms, that all **holes**, **gaps**, **missing faces** on the surfaces have to be repaired.
- Another source of trouble are surfaces with the wrong orientation ("***inverted triangles***"). They should be reversed to the proper orientation.
- There are free software tools that are able to perform such repairs (either automatically or manually) like for example **Netfabb (basic)** and **MeshLab**.



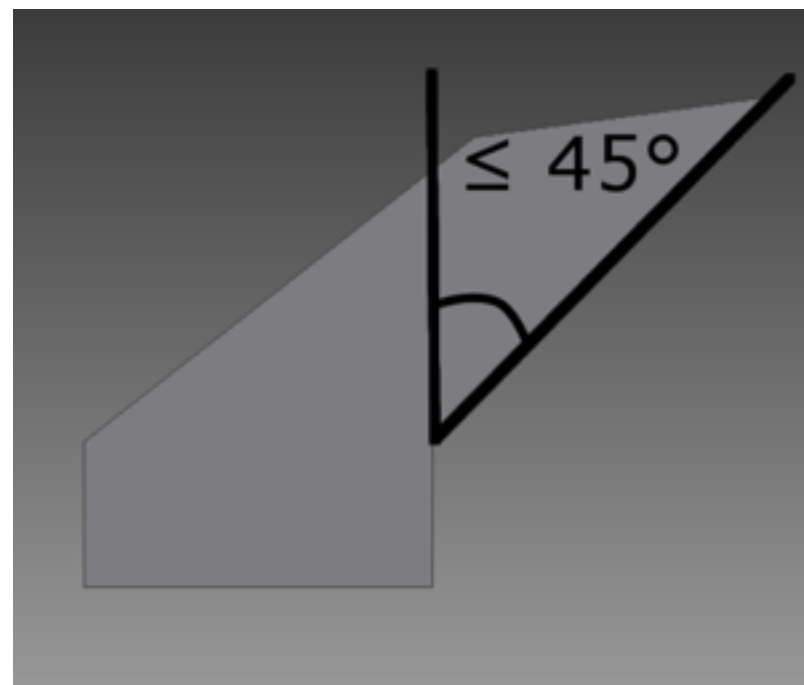
Overhangs



- Sometimes the overhangs can be minimized with a proper rotation of the object
- Other ways to solve this issue:

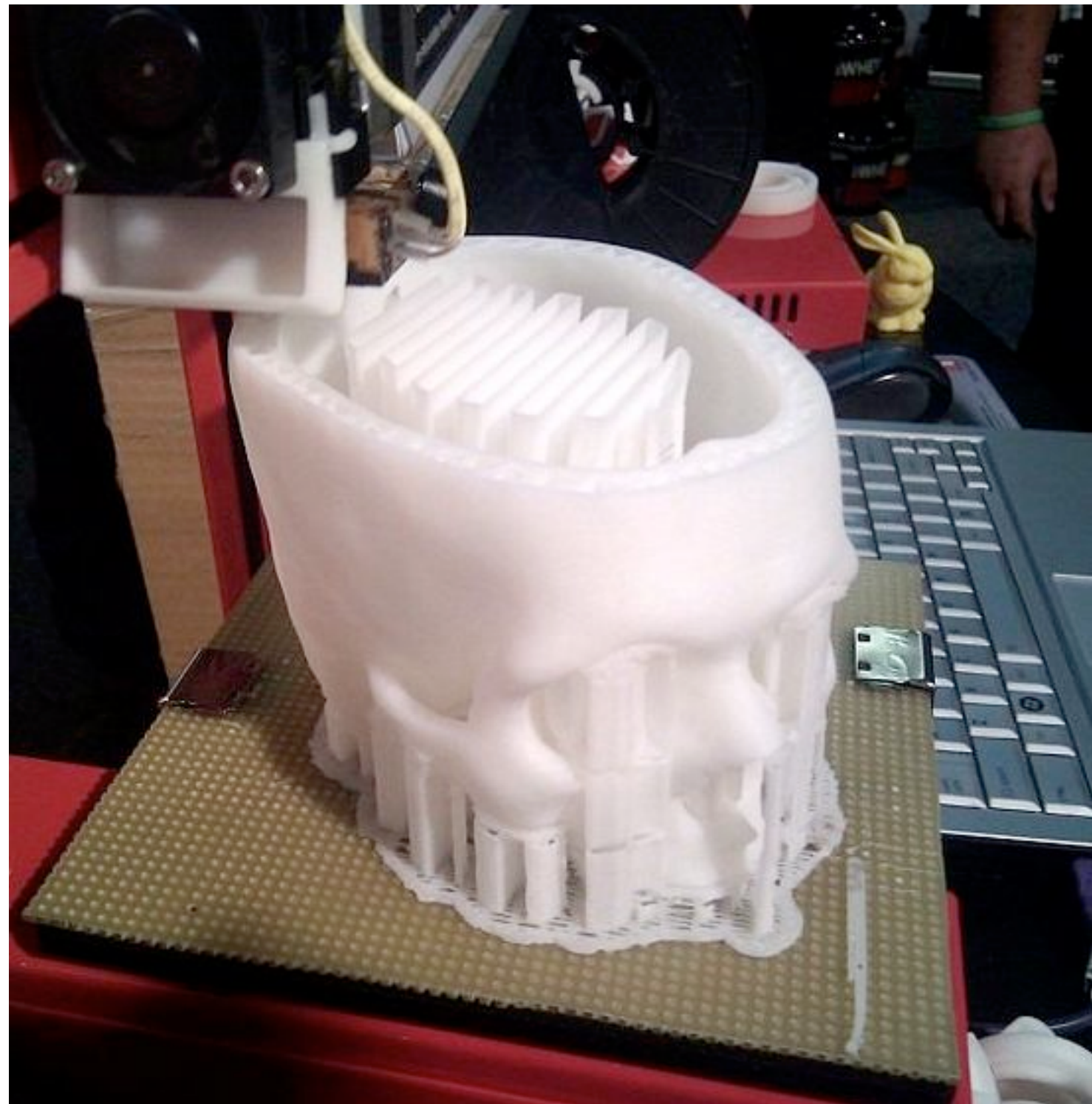


- by cutting the object in more parts (to be glued together)
- by adding some support structures where needed

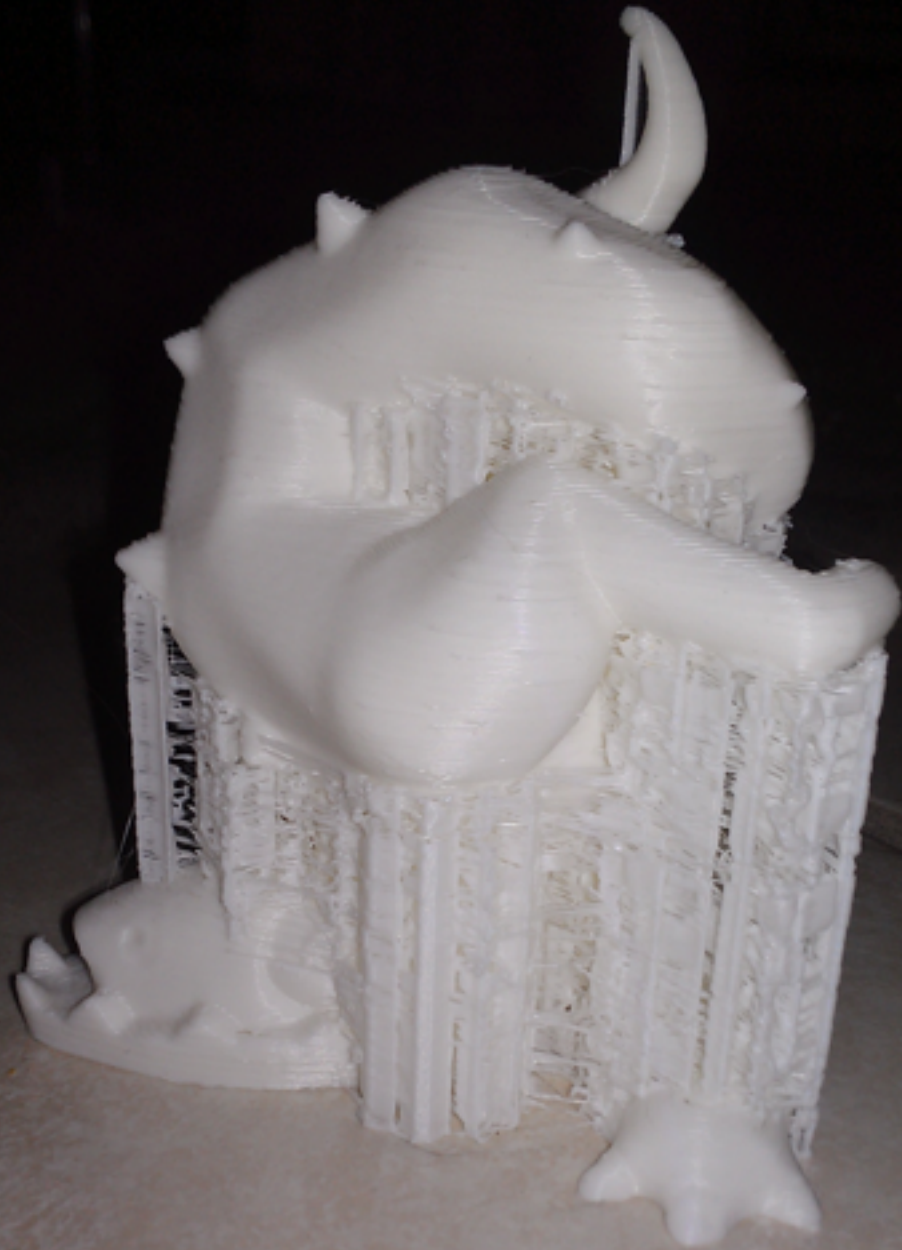


Please, I need support! ;-)

- 3D printers using the FDM technology are not able to print structure with negative or extreme overhangs (think about "stalactites") because these wouldn't be supported by other existing layers during the print. Therefore extra plastic parts called **support** have to be added for such purpose. After the print they can be cut or removed ("cleaning of the support").
- These supports can be generated automatically or manually by most programmes for 3D printing.



Before



CLEANING OF SUPPORT

After

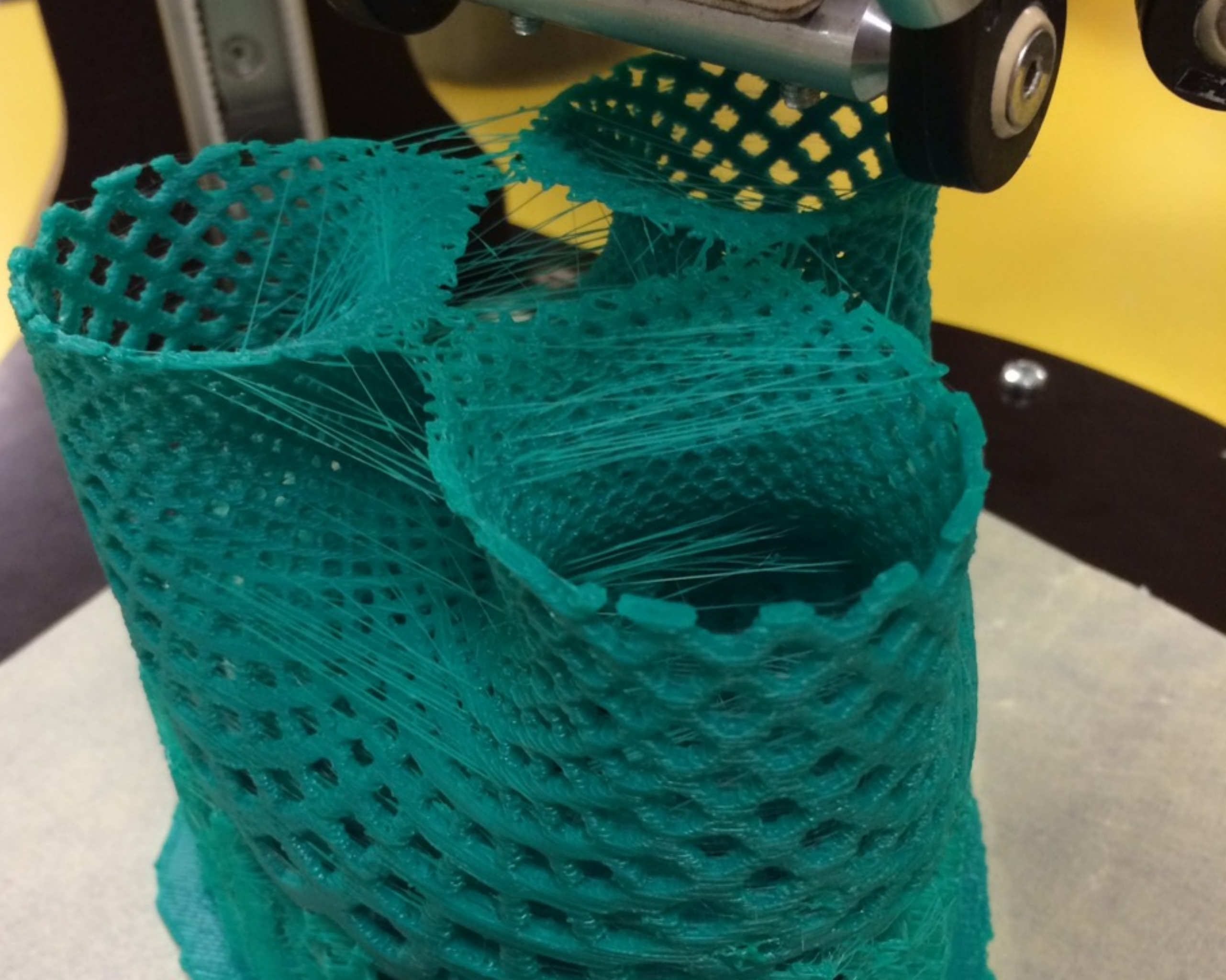


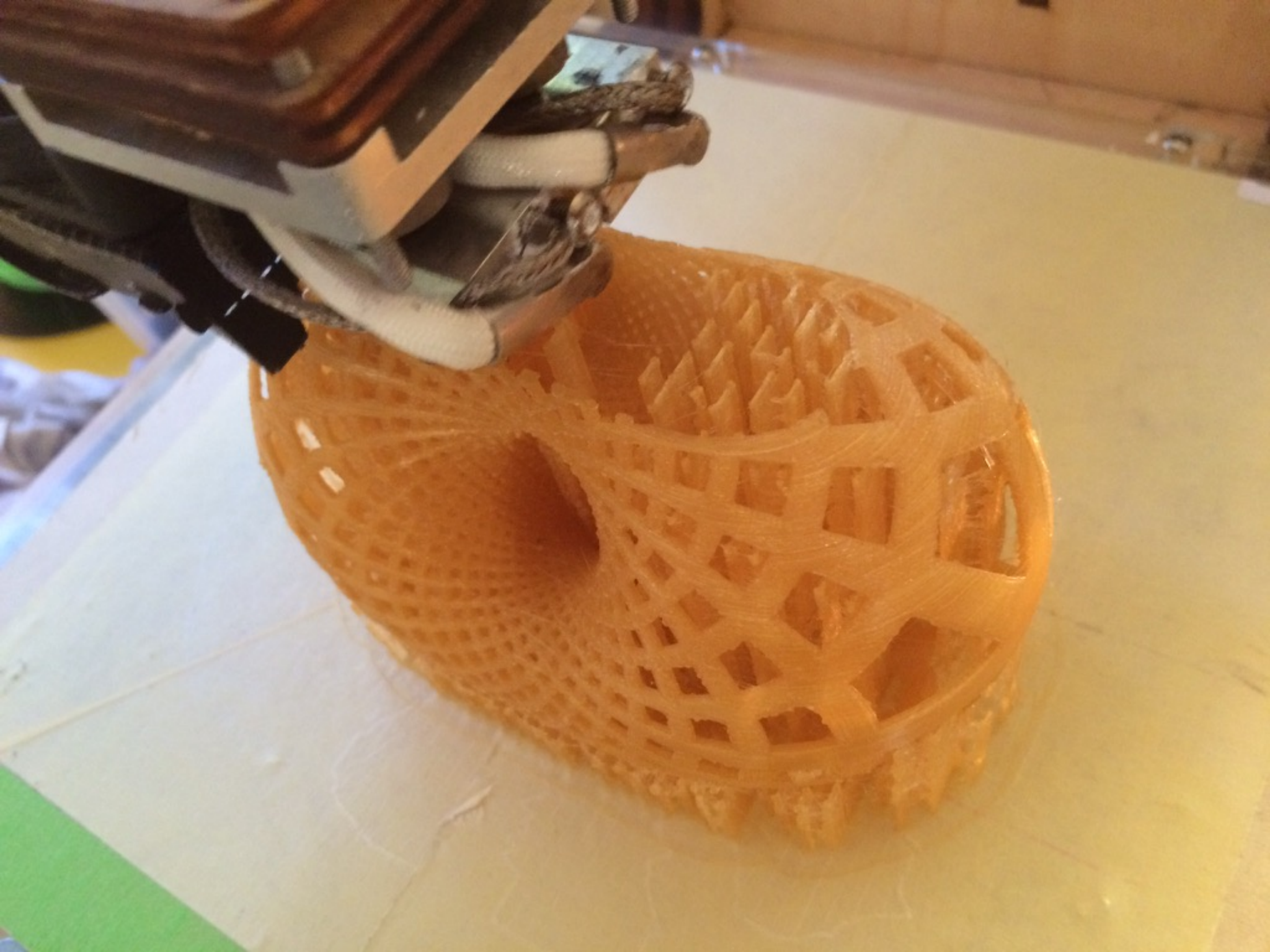


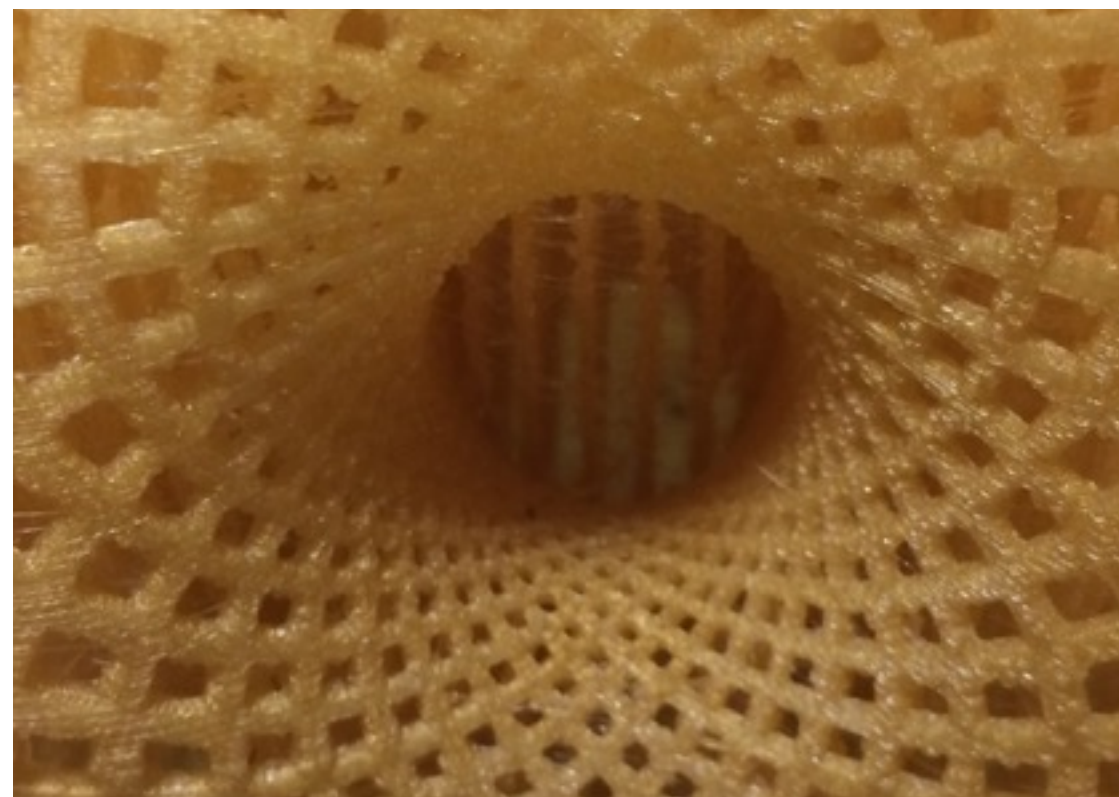
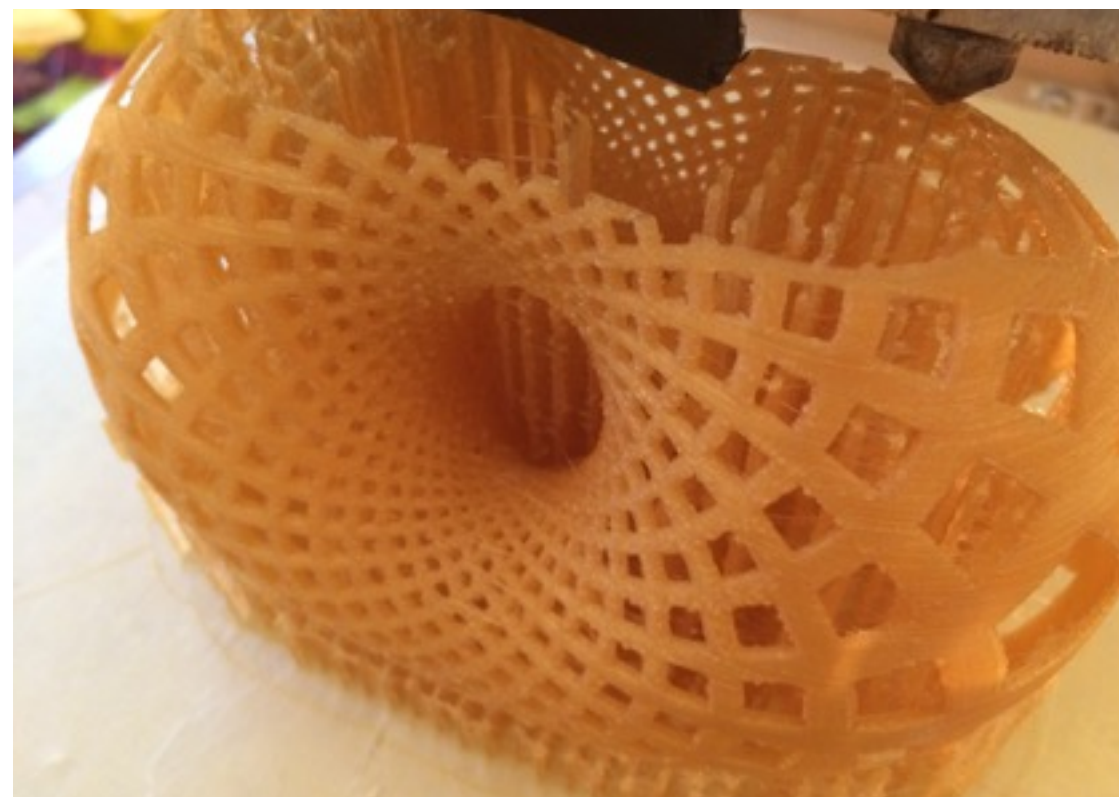
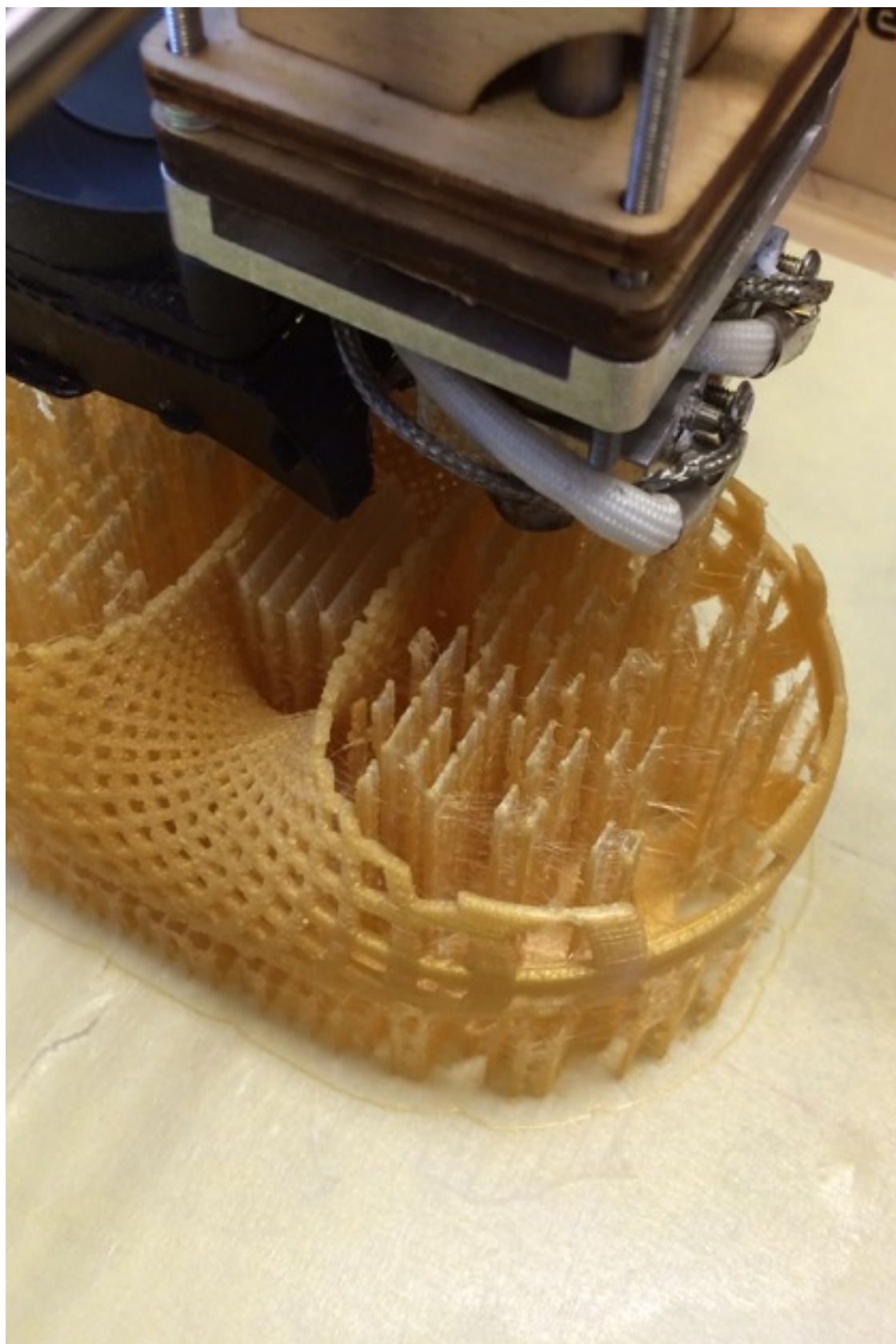
A few images

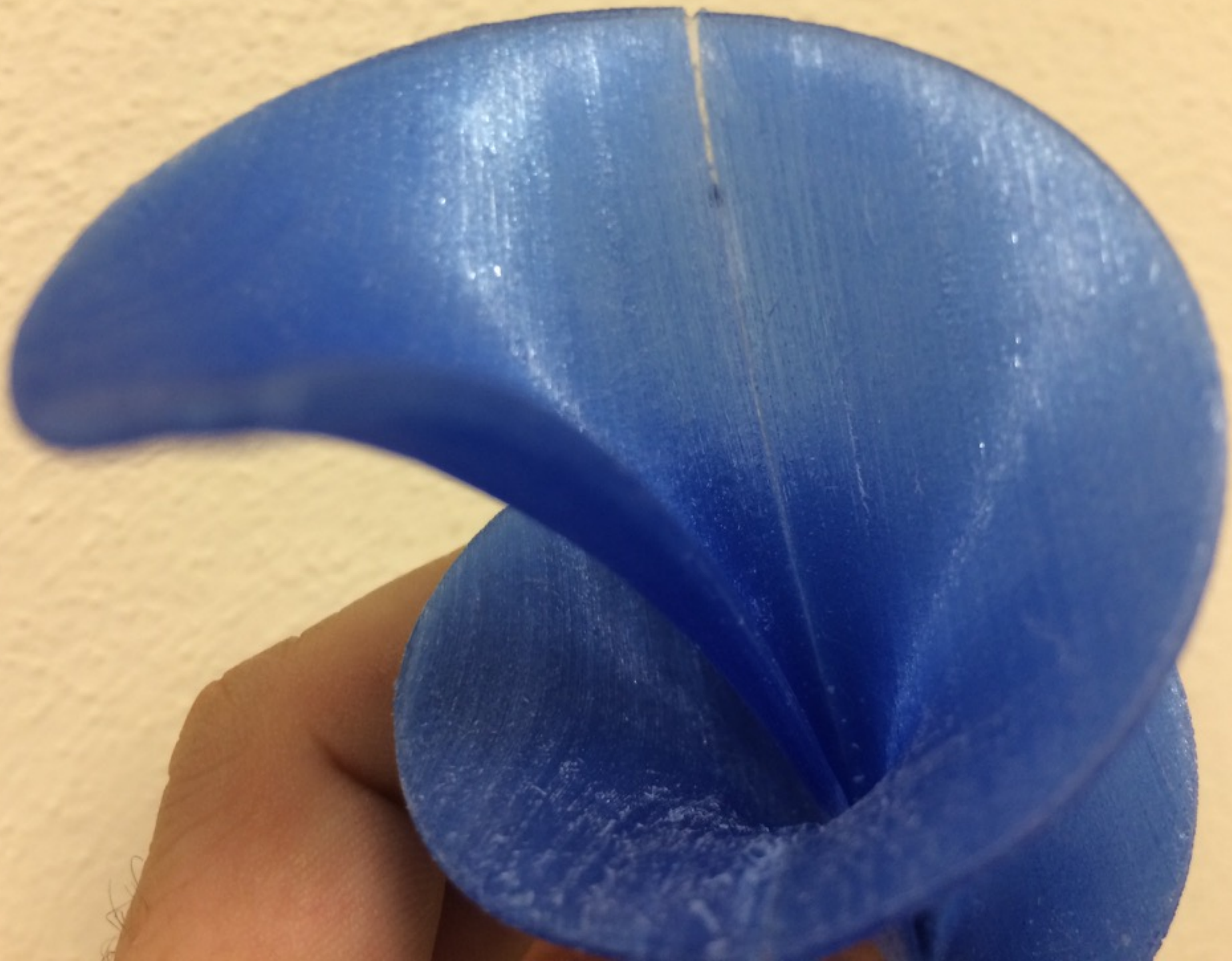
IMAGINARY collection
printed at the ICTP
SciFabLab with FDM
low-cost 3D printers

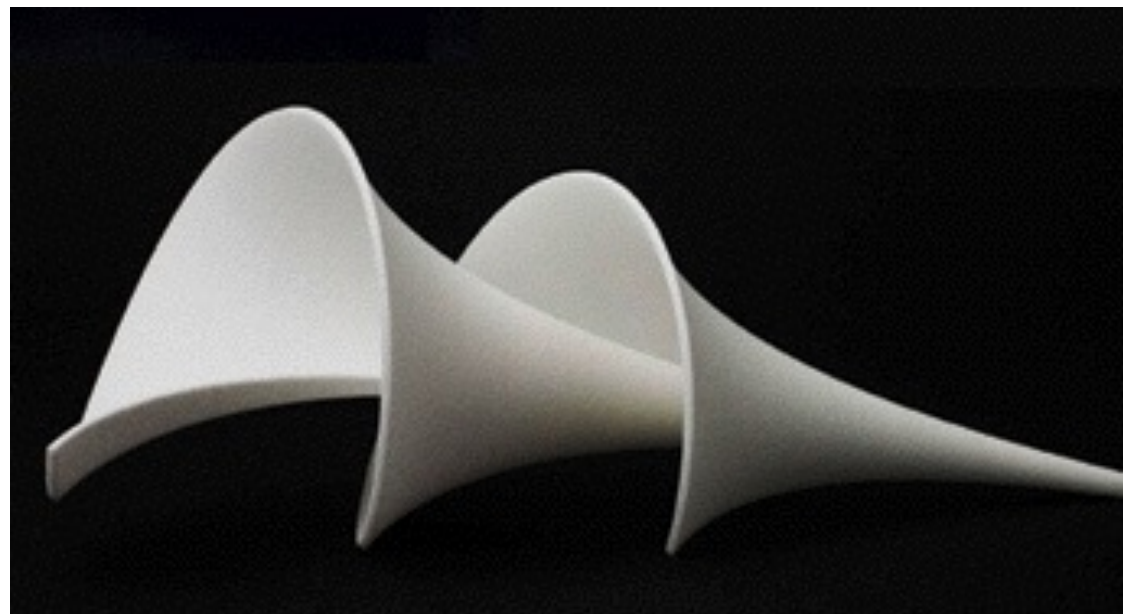














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IMAGINARY Math Exhibition using Low-cost 3D Printers

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(Submitted on 19 Sep 2014)

We have made an attempt to reproduce 17 objects of the IMAGINARY Open Mathematics Exhibition (www.imaginary.org) using low-cost, desktop 3D printers. The IMAGINARY open math is an international project by the Mathematisches Forschungsinstitut Oberwolfach in Germany and includes galleries of volumetric objects that are unique, have aesthetic appeal and mathematical meaning. We illustrate here the printing of these diverse learning materials using new 3D affordable printing technologies based on Fused Deposition Modelling (FDM) and the use of biodegradable plastic PLA. The final goal is to support museums, schools and higher education institutions in countries with lower scientific infrastructure.

Subjects: **Computers and Society (cs.CY)**

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