The SPA, a new miniature MRI-compatible Stepping Piezo Actuator for Bio Medical Applications

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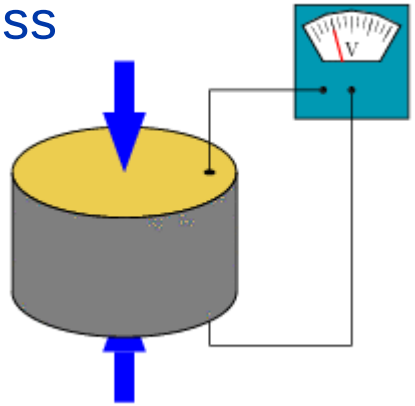
Outline

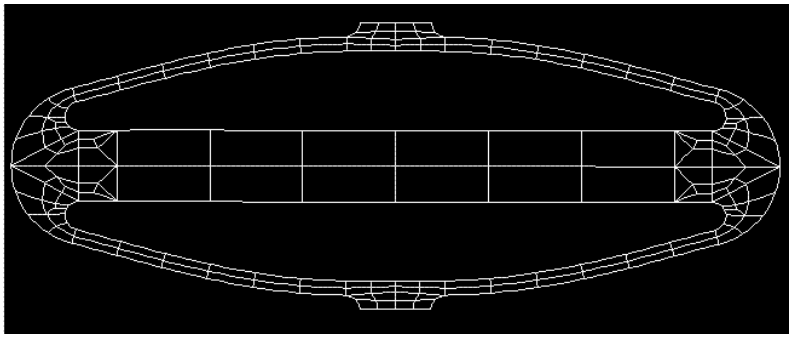
- Stepping Piezo Actuator (SPA) concept
- SPA30uXS
- MRI compatibility
  - Three rules
  - MRI test bench
  - Experimental results
- Conclusions

Piezoelectricity?

- A link between voltage and mechanical stress
  - Direct effect : Sensor
  - Reverse effect : Actuator

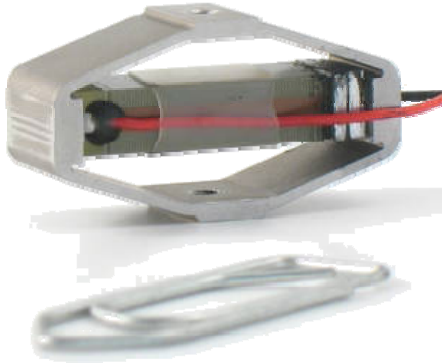


- Amplified Piezo Actuator

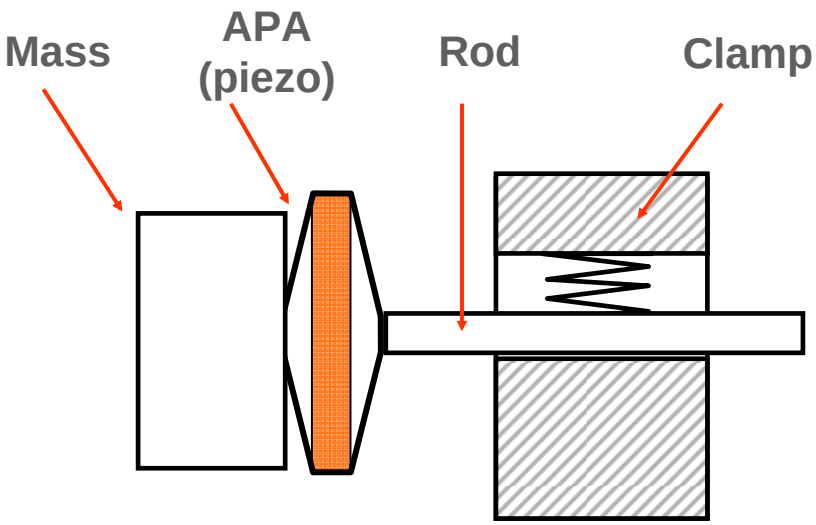


What is the Stepping Piezo Actuator ?

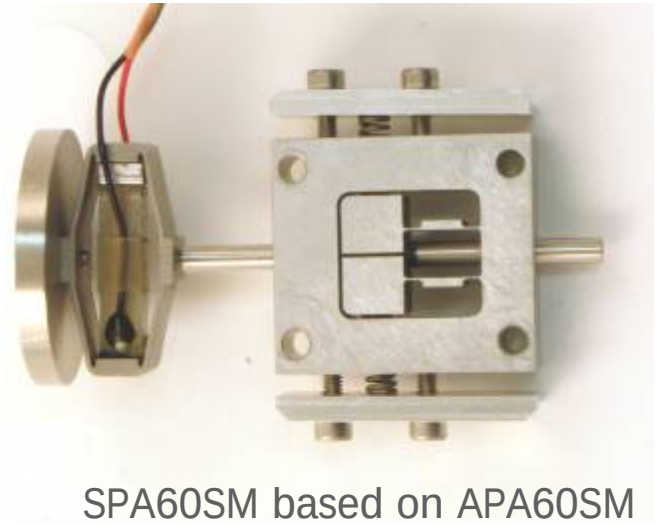
- Linear piezo motor
  - Long stroke (several millimeters)
  - High resolution (nanometer range)
- Components:



APA60SM



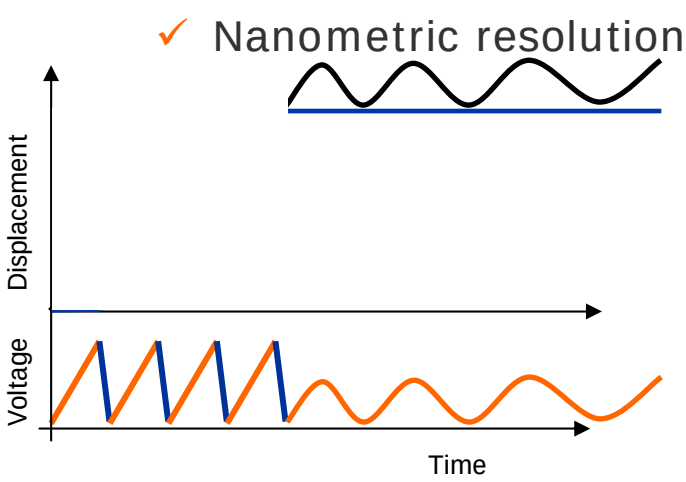
SPA Structure

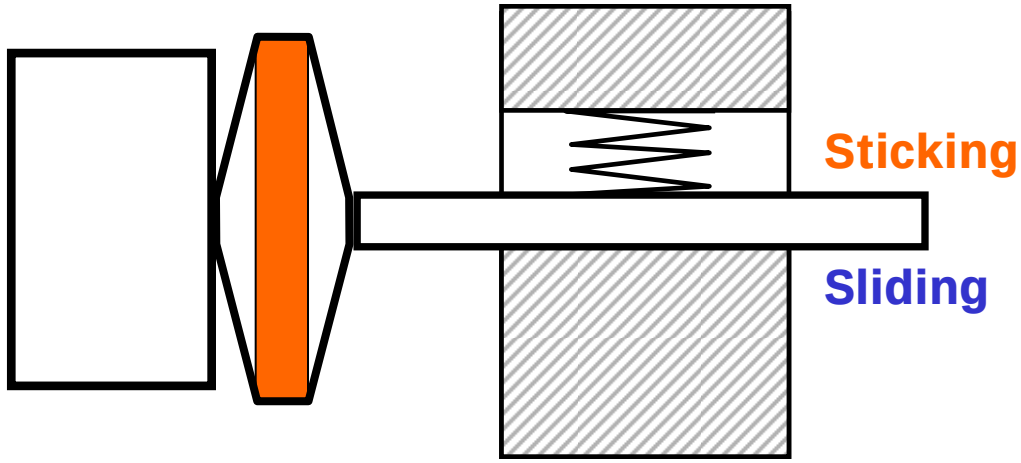


SPA60SM based on APA60SM

How does the SPA work?

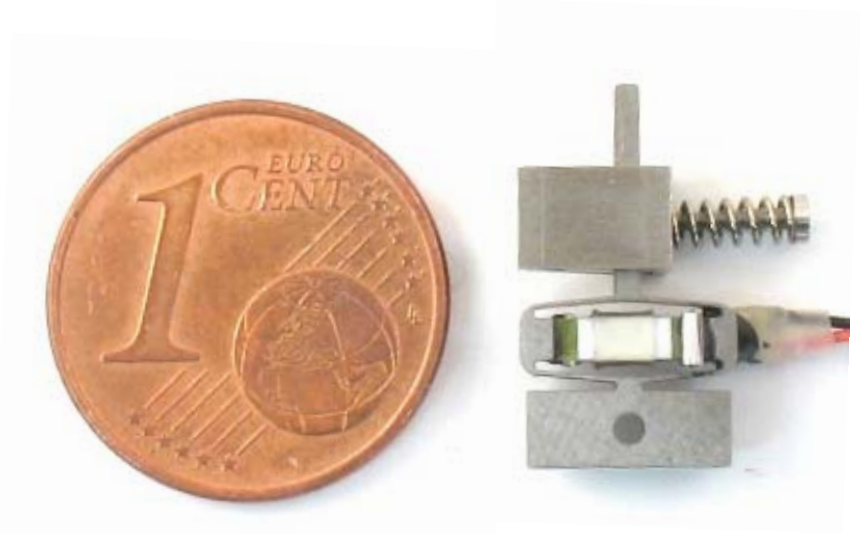
- 2 working modes
  - Stepping mode
    - ✓ Stick and slip
      - Slow contraction
      - Fast expansion
    - ✓ Long stroke
  - Deformation mode
    - ✓ Standard use of Amplified Actuator
    - ✓ Nanometric resolution



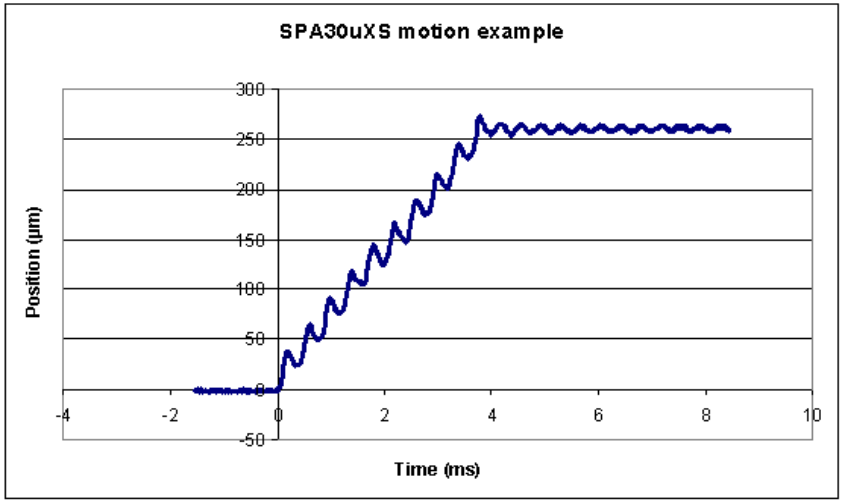


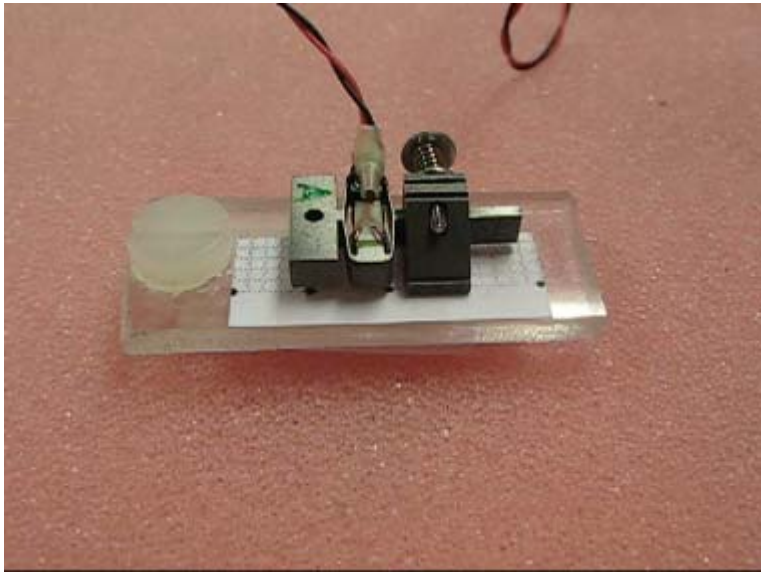
Prototypes

- SPA30uXS
  - Mass: 2 grams
  - Less than 500 mm³
  - Stroke = 4mm
  - Resolution < 5nm
  - Speed : from 0 to 70 mm/s
  - Force : Up to 0,2 N



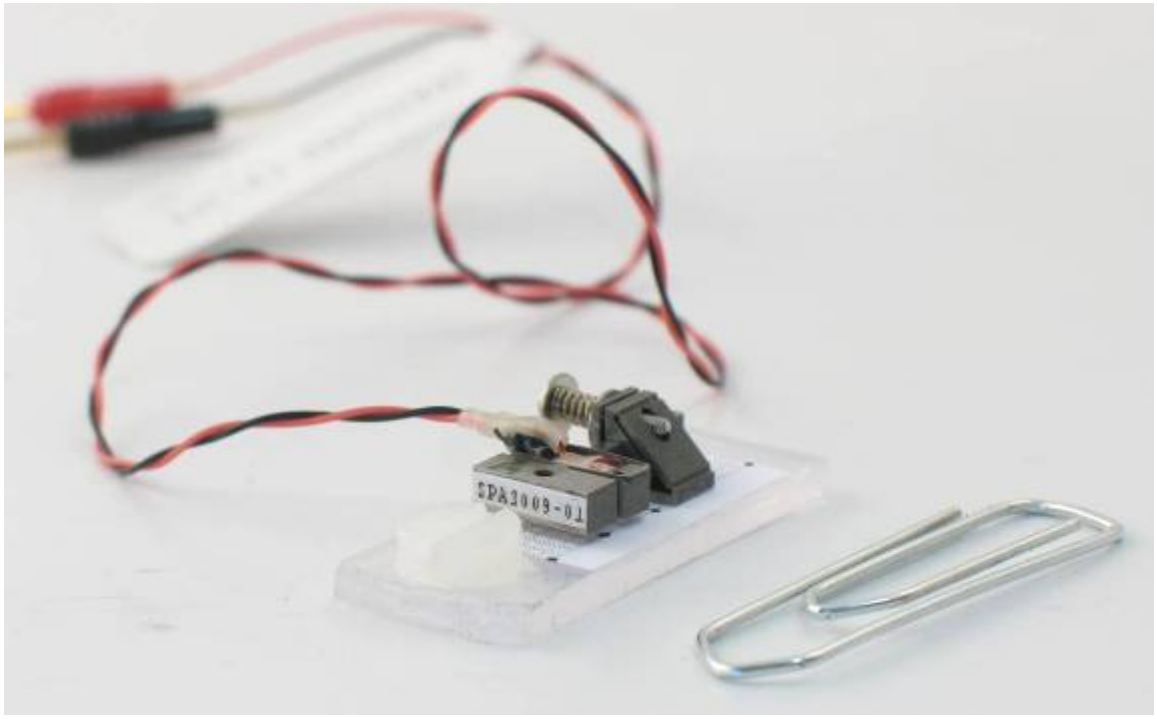
SPA30uXS versus a 1 Euro Cent coin





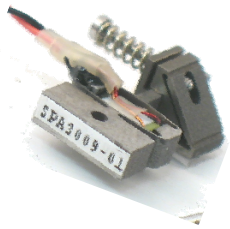
MRI compatibility

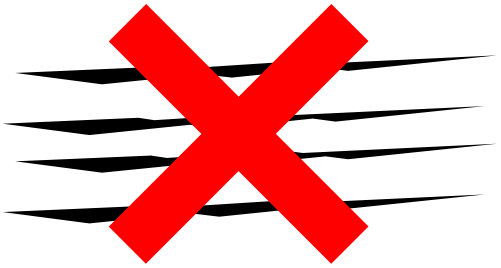
- Three MRI compatibility rules
  - Safety
  - Invisibility
  - Imperturbability



MRI compatibility

- Three MRI compatibility rules
  - Safety: Must not be attracted
    - ✓ Non magnetic actuator
    - ✓ Tests performed into an MRI 4,7 Tesla magnet

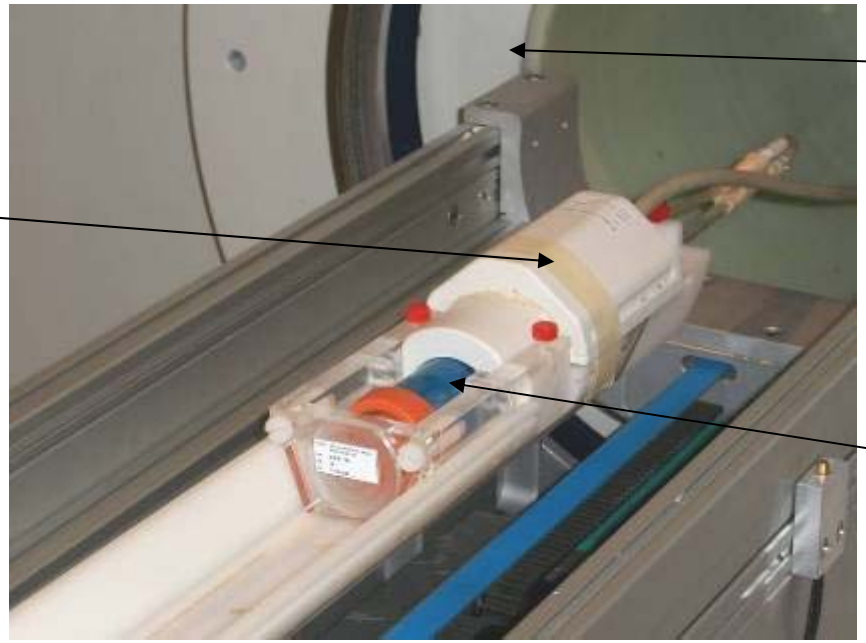




These tests have been performed on Small Animals platform, INSERM Grenoble, France

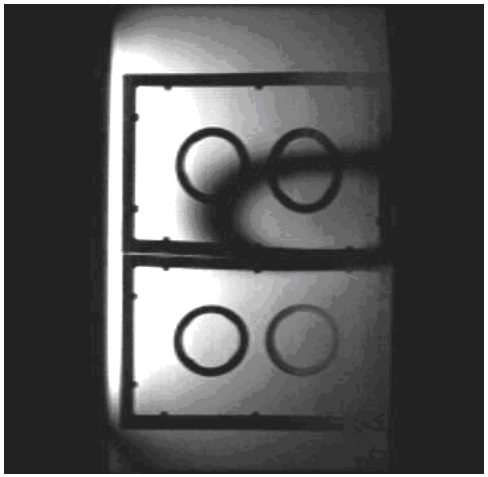
MRI compatibility

- Three MRI compatibility rules
  - Safety
  - Invisibility: Must not trouble MRI scanner and images
    - ✓ Tests performed into an MRI 4,7 Tesla magnet

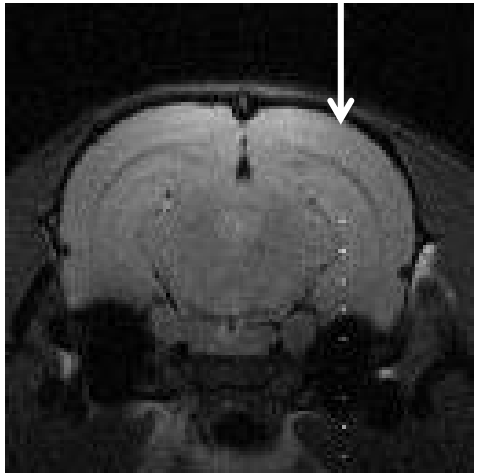


MRI compatibility

- Three MRI compatibility rules
  - Safety
  - Invisibility: Must not trouble MRI scanner and images
    - ✓ Examples of image distortion:
      - Inox screw replaced by Titanium screw
      - Antenna phenomenon caused by wires



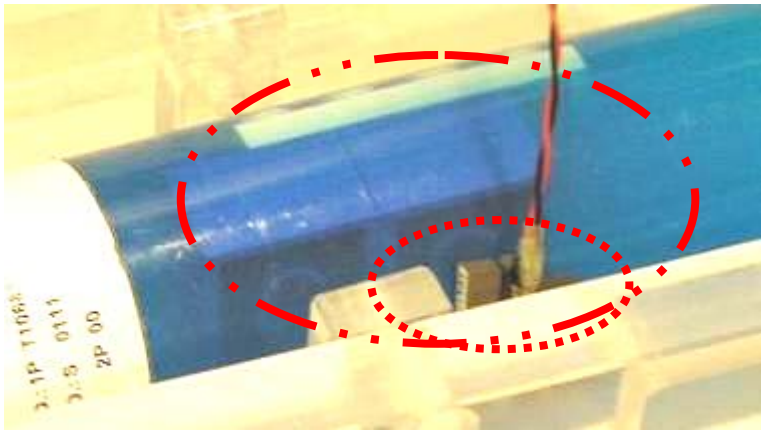
Distortion caused by inox screw



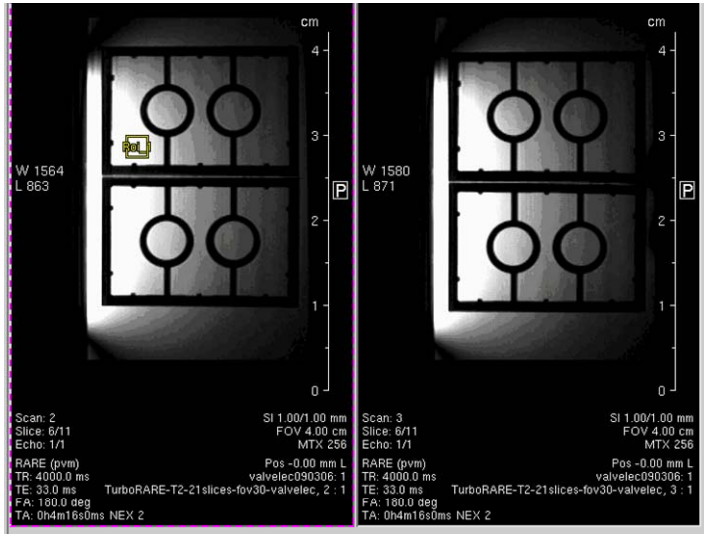
Antenna phenomenon with wires

MRI compatibility

- Three MRI compatibility rules
  - Safety
  - Invisibility: Must not trouble MRI scanner and images
    - ✓ SNR measurement on phantom, realized on 20 images
    - ✓ Without motor : 55.9 with standard variation of 2.5
    - ✓ With motor : 55.7 with standard variation of 2.5

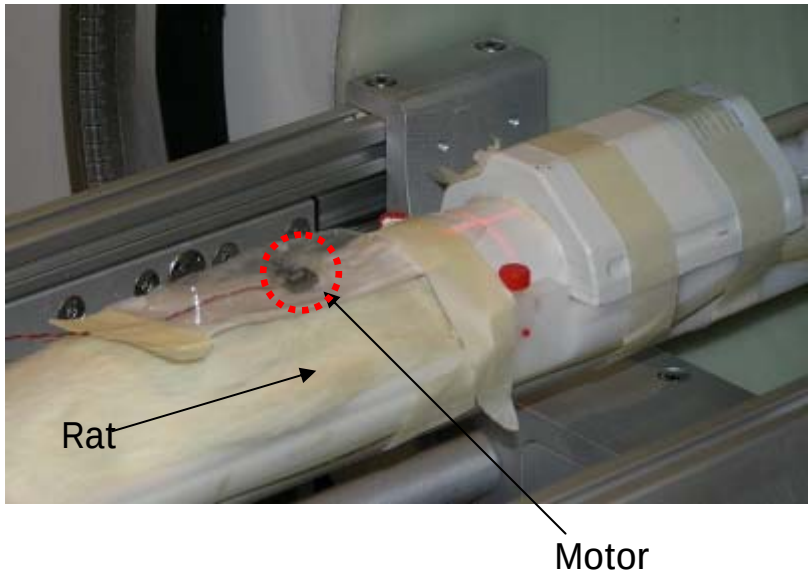


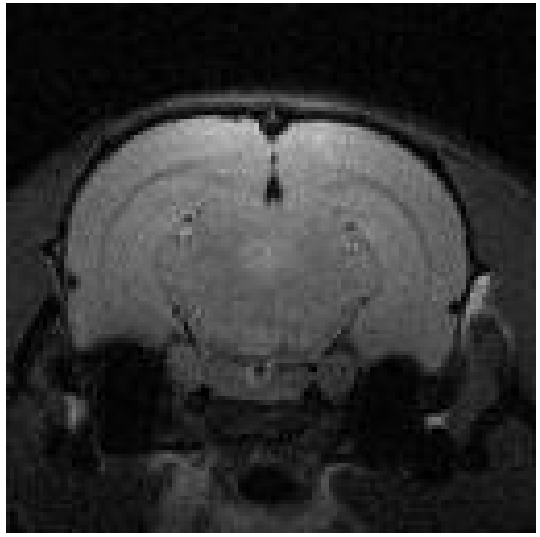
Actuator position (dot) against measured position (dashed)



MRI compatibility

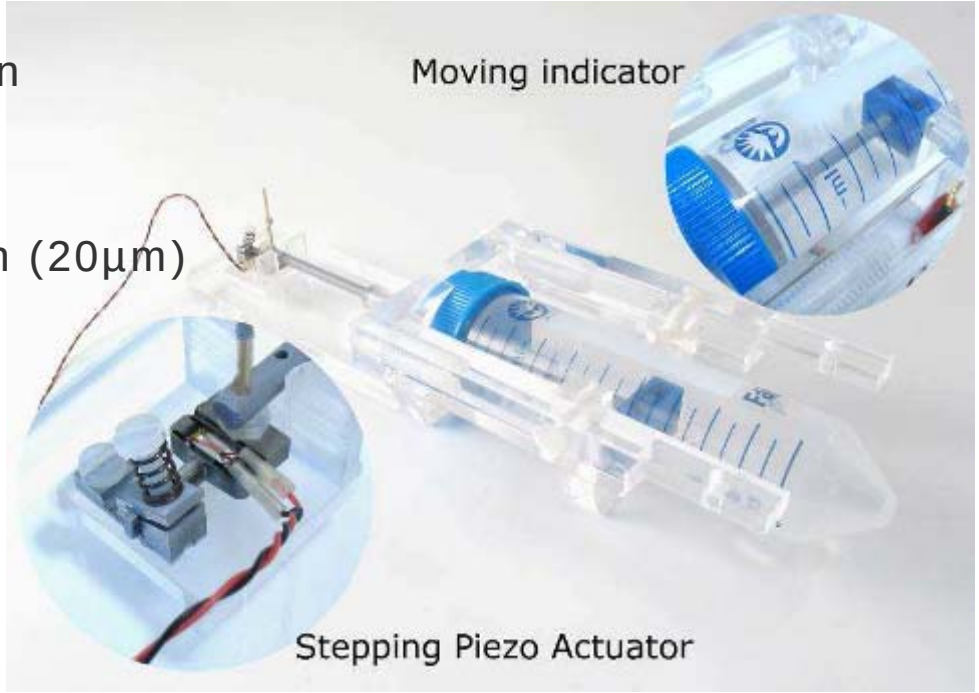
- Three MRI compatibility rules
  - Safety
  - Invisibility: Must not trouble MRI scanner and images
    - ✓ SNR measurement on rat, realized on 10 images
    - ✓ Without motor : 33.6 with standard variation of 1.8
    - ✓ With motor : 32.5 with standard variation of 3.1





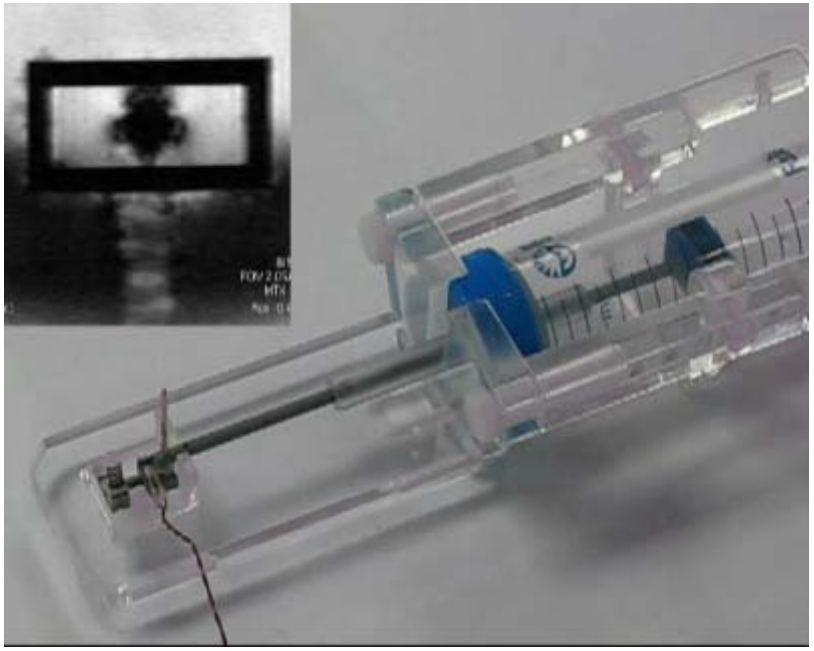
MRI compatibility

- Three MRI compatibility rules
  - Safety
  - Invisibility
  - Imperturbability : Must keep performances within MRI Scanner
    - ✓ Adapted test bench
    - ✓ Axial tool motion simulation
    - ✓ No adapted sensor
    - ✓ Use of Cine-Flash images
    - ✓ MRI high vertical resolution (20µm)
    - ✓ 1 Image/350ms



MRI compatibility

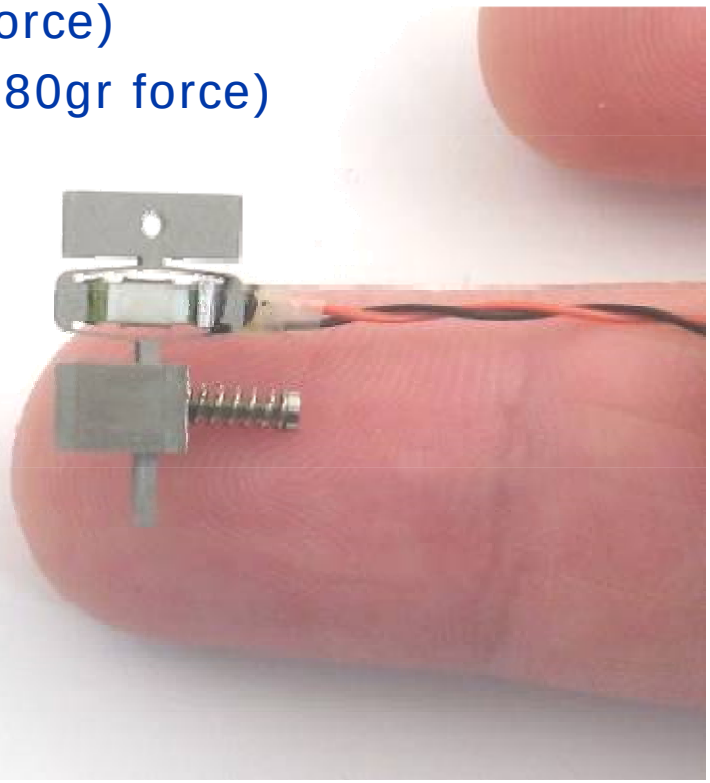
- Three MRI compatibility rules
  - Safety
  - Invisibility
  - Imperturbability : Must keep its performances under magnetic field
    - ✓ No measured perturbation from the high magnetic field



Reconstructed sequence

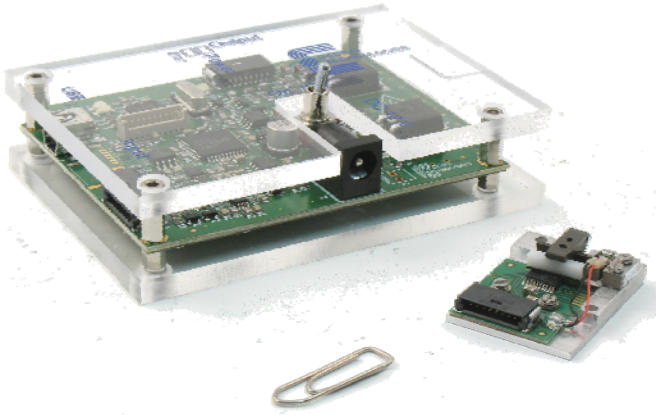
Conclusion (1)

- SPA30uXS quick facts
  - Large linear speed range (from 0 to 70 mm/s)
  - Large linear force (up to 30 grams force)
  - Holding force with no consumption (80gr force)
  - MRI-compatible
    - ✓ Safety
    - ✓ Invisibility
    - ✓ Imperturbability
  - Bio Med Applications in progress
    - ✓ Medical implants
    - ✓ Robotic surgery

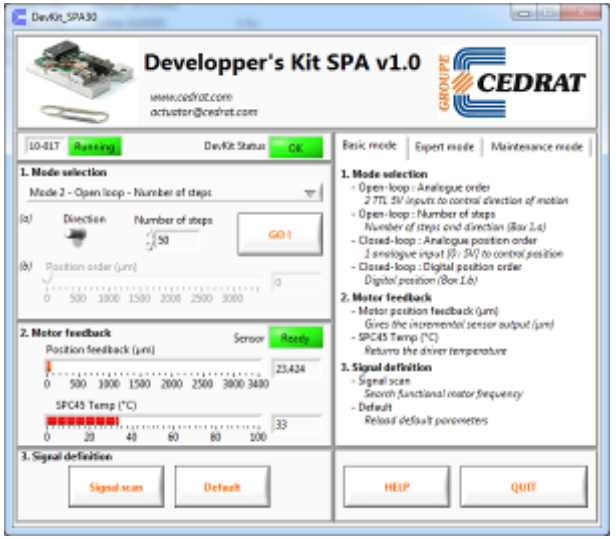


Conclusion (2)

- SPA30uXS commercial availability
  - Stand alone motor
  - Developer Kit including
    - ✓ Motor
    - ✓ Position sensor
    - ✓ Controller
    - ✓ PC interface



- Customised piezo motors
  - Larger-force linear motors
    - ✓ SPA40SM Driving force = 20N
  - Rotational motors
    - ✓ RSPA30uXS



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