TP Robotique: Artificial Muscles (TP 10)

TP Activities

Yegor Piskarev
Bokeon Kwak
Yi Sun

February 2023

Warnings

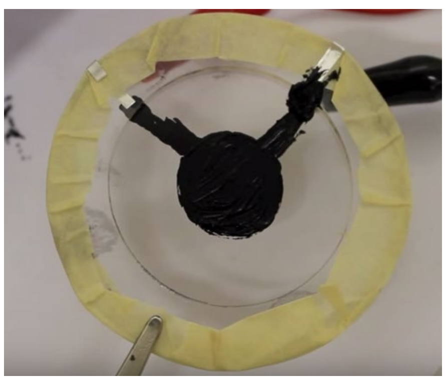
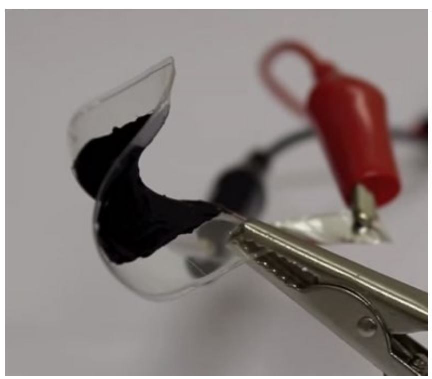
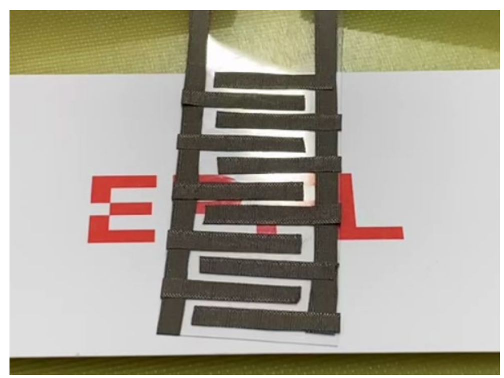
- **NO eating** or **drinking** in lab. Please leave room to do either.
- **Always** wear **gloves** and **goggles** when handling carbon grease and VHB films.
- Work on top of designated areas. Keep devices on paper towels to prevent spread of carbon grease.
- If you need to clean up a mess, use paper towels and a solvent if necessary. Remember gloves and goggles!
- Be **very careful** when working with **High Voltage**. Be sure to check that the power is off when connecting and disconnecting the wires. Also, before turning on the voltage, make sure that there are no possible shorts with wires, metal objects, other electronics, etc.

Material properties

- Acrylic elastomer film (unstretched) (3M, VHB 4905)
  - Thickness: 508 um
  - Young's modulus: ~200-600 kPa
  - Relative permittivity: 4.68
  - Breakdown strength: 24.8 V/um
- Polyester frame (Dura-Lar)
  - Young's modulus: ~5 GPa
  - Thickness: 203.2um (0.008")
- Carbon grease (MG Chemicals, 846)
  - Volume resistivity: 117 Ω-cm

Outline

- Part I: DEA Circle Actuators
- Part II: DEMES
- Part III: Electroadhesive devices (2d week)
- Part IV: Robot! (3d week)

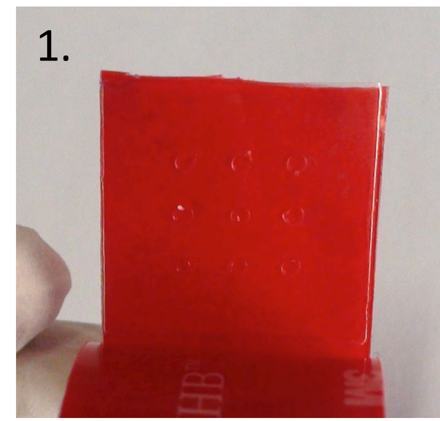




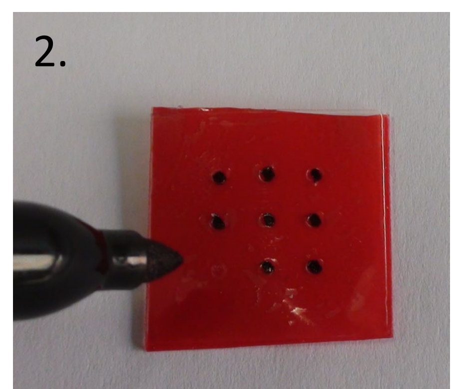

Part I: DEA Circle Actuators

- The purpose of this part of the laboratory is to explore the effects of prestrain on VHB 4905 acrylic elastomer.
- This is accomplished by,
  1. Creating circular DEA actuators with varying prestrains, 200-400%.
  2. Characterizing **Area Strain** vs **Voltage** and vs **Time**.

Part I: DEA Circle Actuators

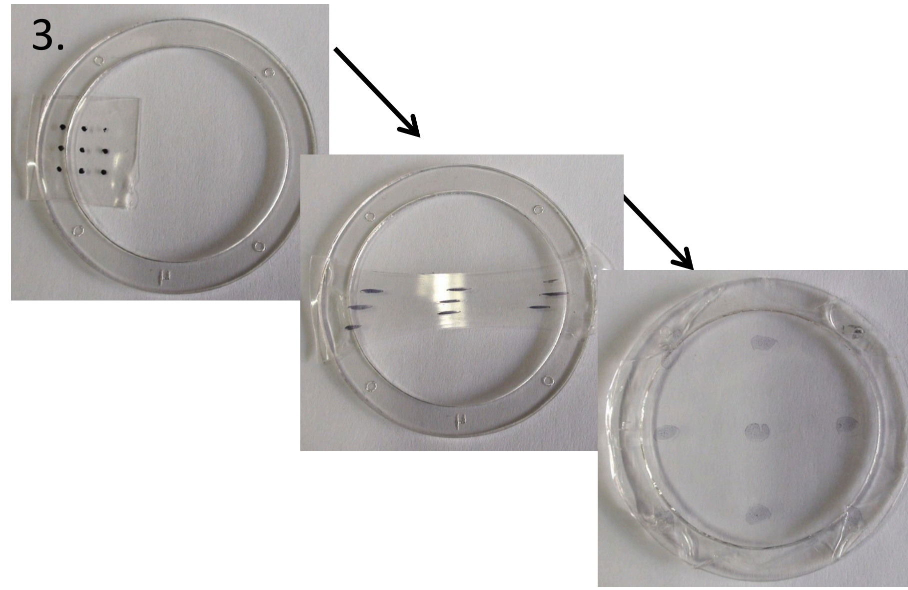
- Fabrication:
  1. Apply 1 inch square plastic stencil with 5 mm square hole array on the sticky side of the VHB 4905 tape, and then cut off tape.
  2. Use stencil to apply permanent marker, and then remove stencil and tape backing. The dots will allow measurement of prestrain after stretching.

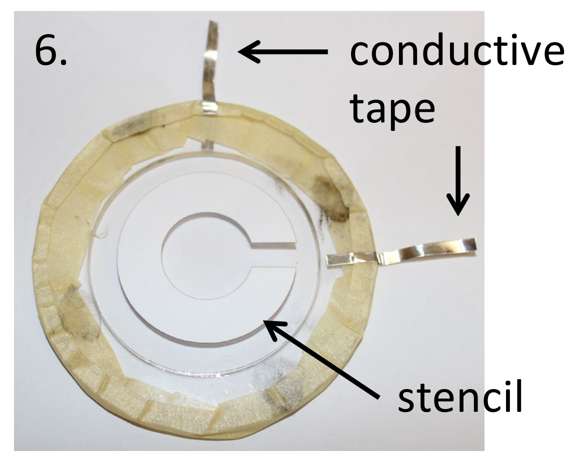




Part I: DEA Circle Actuators

- Fabrication cont’d:
  3. Stretch VHB film across circular frame in one direction. Then continue stretching in a circular direction until uniformly stretched. Measure prestrain. Note: the number on the frames corresponds to the stretch ratio, where **stretch ratio=1+%prestrain/100**.
  4. Apply masking tape around edge of ring to keep VHB from detaching.
  5. Then, apply conductive tape. One on each side of frame and at 90°. Do not let tape touch active area (may cause a puncture).
  6. Lay down first electrode stencil.

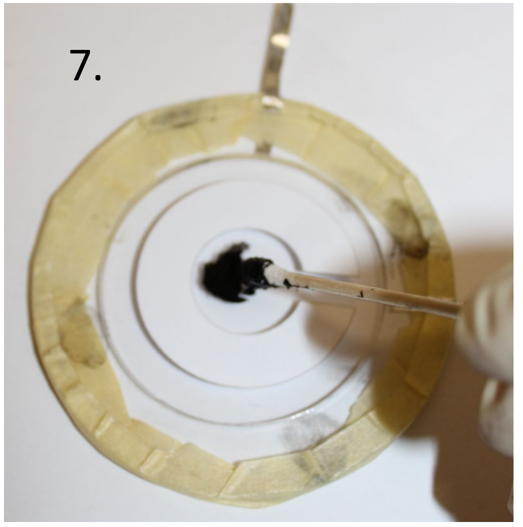


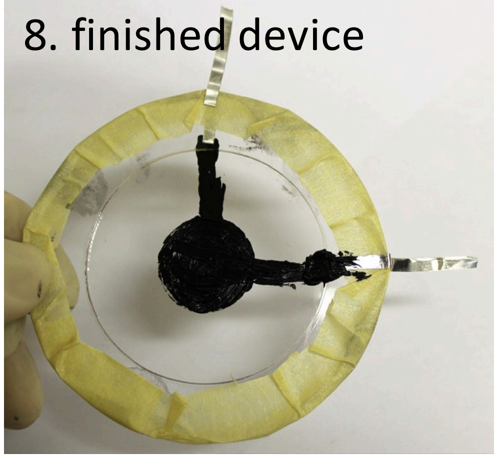


frames

Part I: DEA Circle Actuators

- Fabrication cont'd:
  7. Fill in stencil with carbon grease. Flip and repeat at 90°.
  8. Sample is now ready to test.



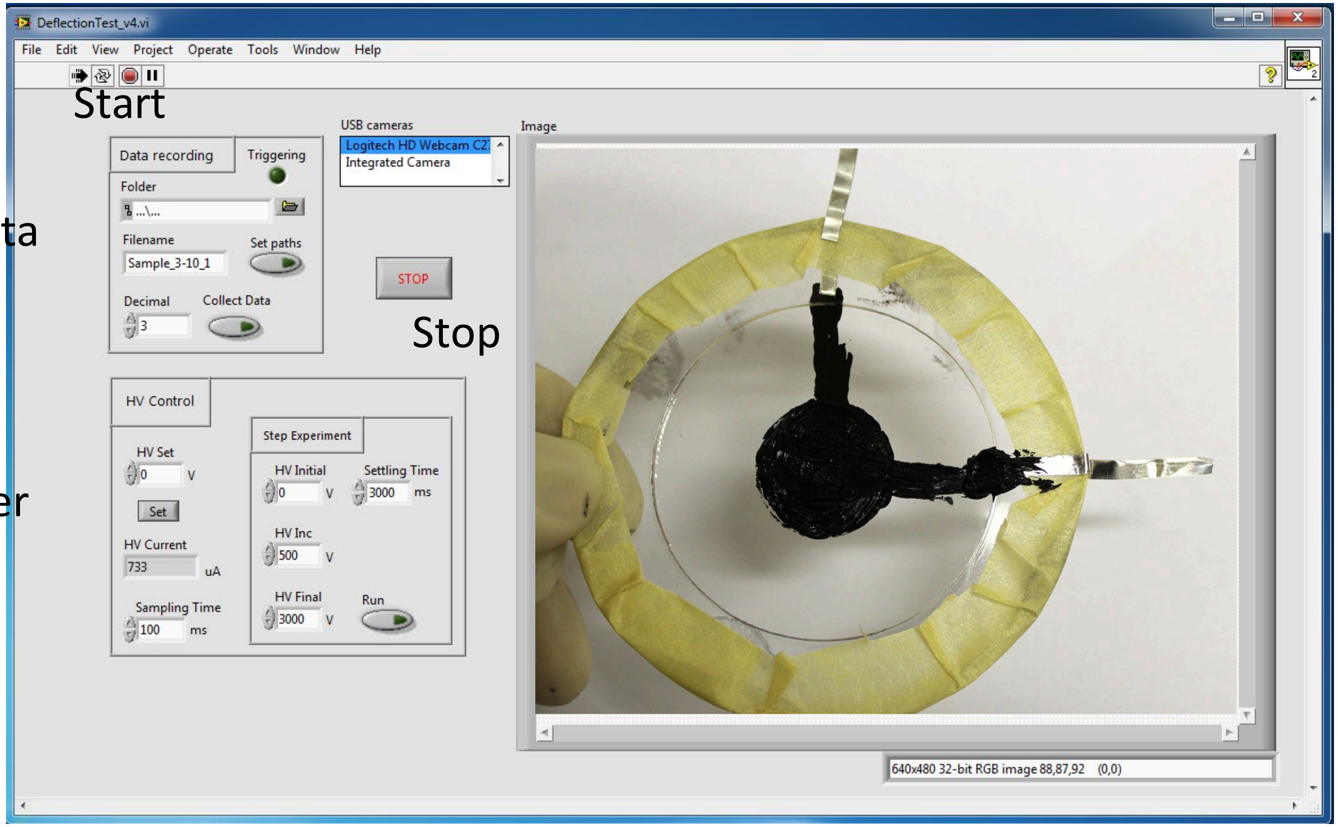


Part I: DEA Circle Actuators

- Experiments:
  - For each different prestrain (200%, 300%, 400%), repeat the following experiment:
    1. Fix camera so that it is looking down at the sample.
    2. Use LabView program shown on next page to apply a fixed voltage starting at 0 kV and increasing in increments of 0.5 kV up until 5 kV or breakdown failure, whichever comes first.

Part I: DEA Circle Actuators

- Experiments:
  - For **area expansion** measurements:
    - LabView program that steps through a predefined range of voltages and takes a picture at each step.



Part I: DEA Circle Actuators

- **Report** - Analysis:
  - Generate the following plots from your recordings:
    1. **Area Strain** vs. **Voltage** at fixed time, all prestrains on same plot.
    2. **Area Strain** vs. **Electric Field** at fixed time, all prestrains on same plot. Estimate sample thickness based on prestrain.

Part 1: DEA Circle Actuators

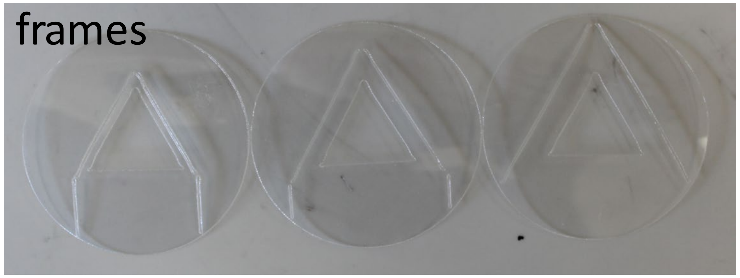
- **Report** - Conclusions:
  - Consider the following questions when describing your results in the report:
    1. Based on the fundamental equations and change in material properties for prestrained films discussed in the lecture. Why do you see the trends represented by your data? Do you think you would see a benefit from even higher prestrains?
    2. What prestrain would be best to use in an actuator and why? Consider force, strain, robustness, etc. when making your arguments.

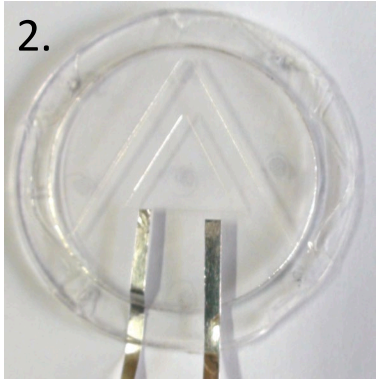
Part II: DEMES

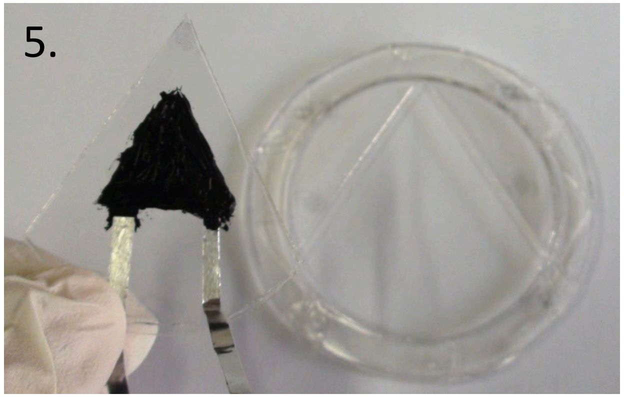
- The purpose of this part of the TP is to see the effect of changing frame stiffness of a DEMES device with constant DEA area.
- Fabrication:
  - All of the DEMES actuators are fabricated in the same way. Only, the frame will change.
    1. Prestrain film to desired prestrain using circular frame number 5 (400% prestrain) as shown in Part I. Make sure all devices have near the same prestrain for comparison purposes.

Part II: DEMES

- Fabrication:
  2. Attach frame to the stretched film. Make sure to press down until well adhered. Attach conductive tape on both side of frame. Do not let tape touch active area (may cause puncture).
  3. Paint on carbon grease electrodes using a Q-tip and the frame opening as a guide. Try not to get too much carbon grease on the frame.
  4. Use razor blade to cut out frame.
  5. Sample is now ready to test.

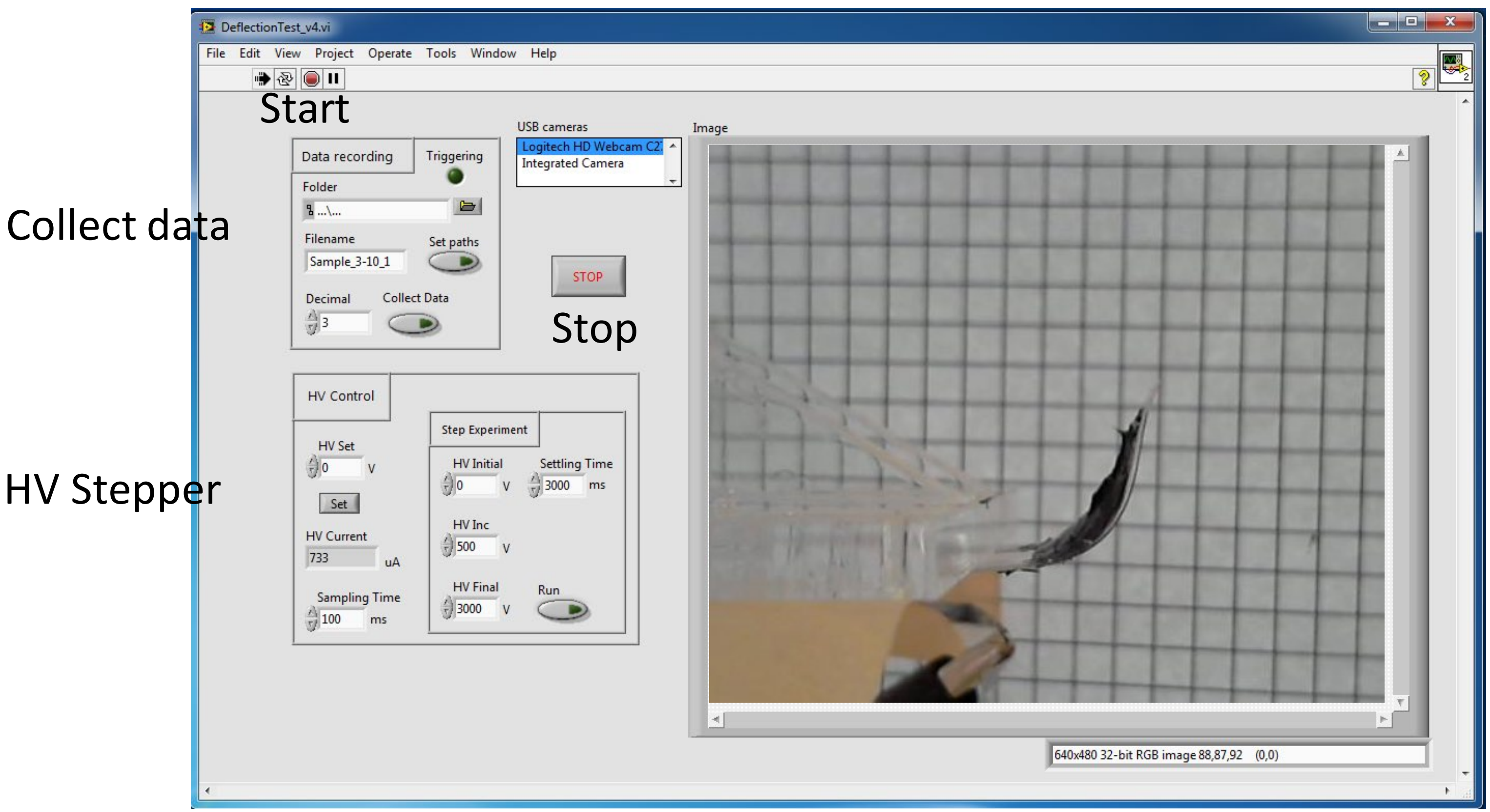






Part II: DEMES

- Experiments:
  - For **Deflection** measurements:
    - LabView program that steps through a predefined range of voltages and takes a picture at each step.



Part II: DEMES

- **Report** - Analysis:
  - Generate the following plots and figures for all the tested DEMES devices:
    1. Deflection vs Voltage. Deflection may be in terms of degrees or length.
    2. Figure showing how you measured deflection (how you define the relative angle or length change).

Part II: DEMES

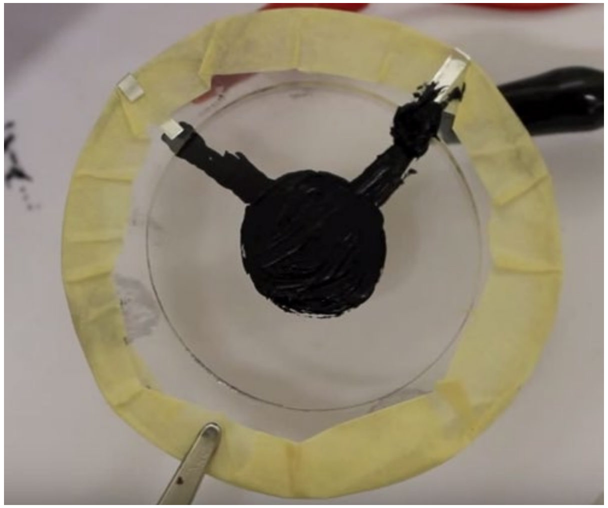
- **Report** - Conclusions:
  - Consider the following questions when describing your results in the report:
    1. Which actuator had the highest deflection? Explain why you think this is the case using arguments of force, area, energy, or whatever details you think are pertinent.
    2. How could you change these devices to get higher force? higher displacement?

Part III: Electroadhesive devices

- At the start of the second session, TAs explain you how to assemble an electroadhesive (EA) pad.
- All the components will be provided.
- Next, three types of EA pads will be tested using a universal testing machine (Instron) to determine the shear forces generated by pads.

Part IV: Robot!

- Use all the knowledge that you have gained in Parts I & II to make a walking (crawling, scooting, slithering, etc.) robot that has the longest gait (distance traveled per actuation cycle).



Part IV: Robot!

- Robots are based on DEMES.
- Prepare frame design of robots (ideally before starting).

Part IV: Robot

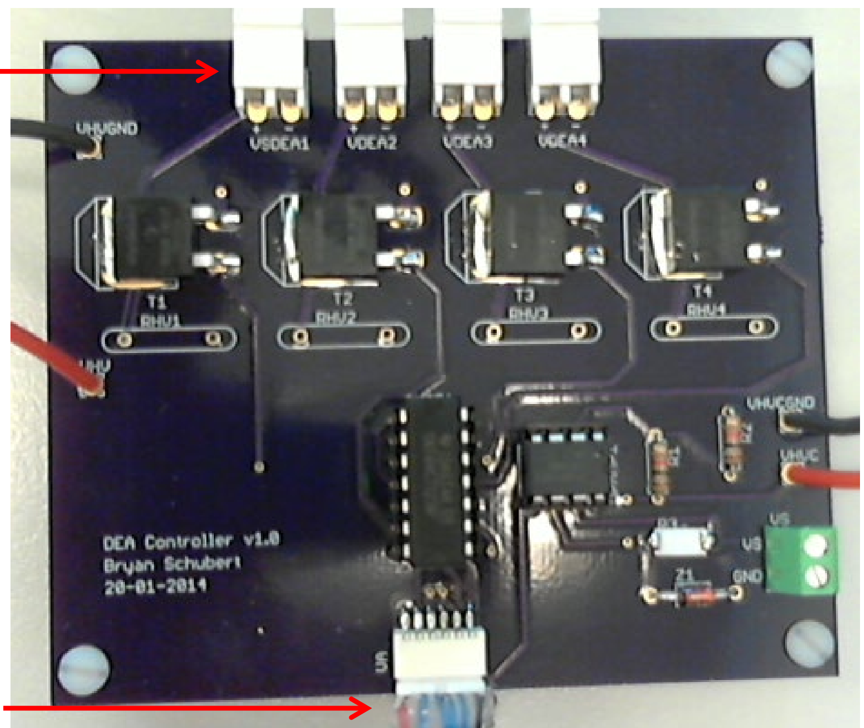
- The designs can be drawn in any vector drawing program (CorelDraw X5, AutoCad 2011, Inkscape, Adobe Illustrator, SolidWorks, etc.). The drawing should be saved as *.xps for printing with the laser. This can be done on Windows PCs by printing to a file using the Microsoft XPS printer.
- The SolidWorks drawings for the DEMES frames can be found on Moodle.

Full Spectrum Hobby Laser
fslaser.com

Part IV: Robot

- Actuator Controller: **Hardware**
  - Control of the robot actuators can be accomplished with the DEA Controller board shown below.
  - This board allows the control of up to 4 actuators, with a maximum actuation voltage of 3 kV.

HV Outputs



PC Control Signals

Part IV: Robot

- Actuator Controller: **Software**
  - We have a MATLAB script, which generates digital signals to control the HV switched on the control board.
  - The **period**, **delay** and **duty cycle** of the 4 signals determines the actuation sequence. By modifying these values you can control the gait of your robot.
  - Prepare the command sequence and give it to your TAs during the 3d session. They will program everything for you.

Part IV: Robot

- **Report** - Analysis:
  - Take pictures of your device, including fabrication and completed device.
  - Generate plots to characterize the pertinent properties of you robot (gait length, speed, etc.).
  - Record device performance (i.e. photos, frames from videos, gait timing, etc.).
  - If time allows, compare multiple designs.

Part IV: Robot

- **Report** - Conclusions:
  - Include the following information in your report:
    1. What motivated your design choices? Consider fundamental equations, physics (e.g. friction, gravity, etc.).
    2. Did your device perform as expected? Explain, citing unexpected performance (both bad and good).
    3. How would you improve your design? Explain.

Evaluation and Report

- Report size is **10** page max including absolutely everything **(**reproof: – 1 of the final grade).

	Comments	Weight	Mark
DEA Results Discussion	+ Accomplished all the goals - There is a lack of data for thickness change, which leads to vague discussion on strain generation	20%	5
DEMES Results Discussion	+ Accomplished all the goals	20%	6
EA Results Discussion	+ Accomplished all the goals - The discussion part about the influence of applied voltage on the distance between electrode is unclear	20%	5.75
Robot Idea Modelling Design Implementation	+ Good modelling - The working robot was not achieved. Probably, the robot performance had to be checked more frequently during the practical session.	30%	4.75
Working Style Autonomy Communication with assistants Timeliness	+ Generally autonomous + Very prompt updates – no delays in meeting set commitments	10%	6