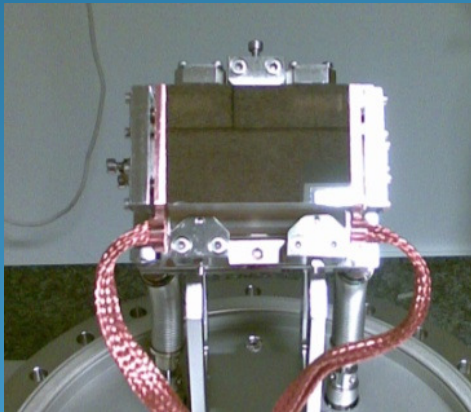


ASTRID2 og DNA set med en fysikers øjne

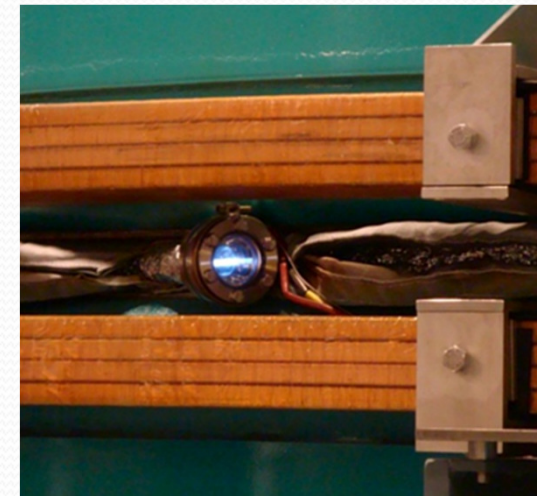
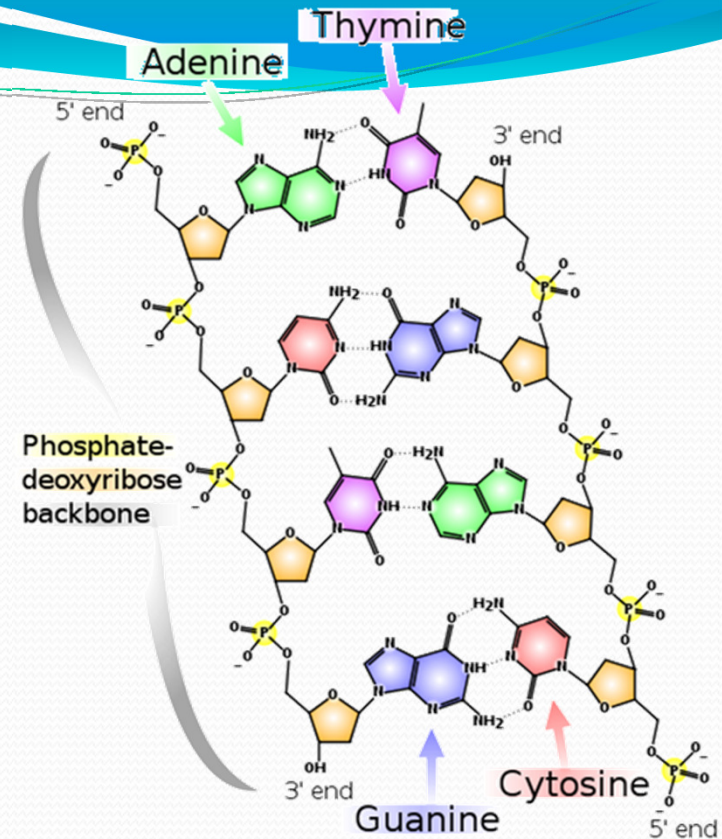


Søren Vrønning Hoffmann
Fysiklærer dag, IFA, Aarhus Universitet, Januar 2013

Introduktion

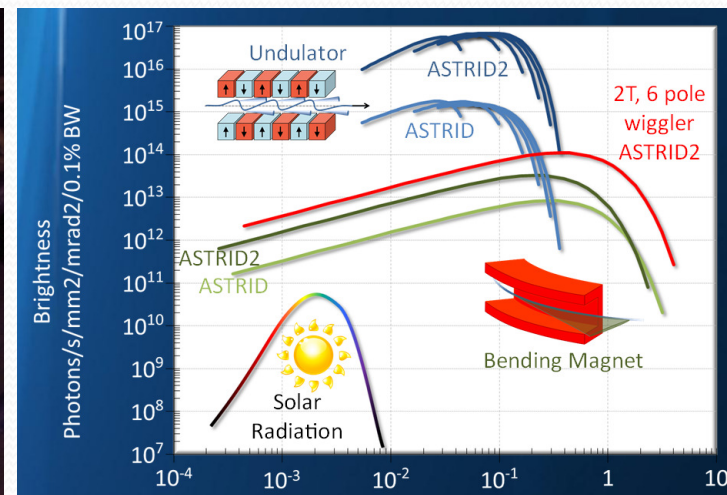
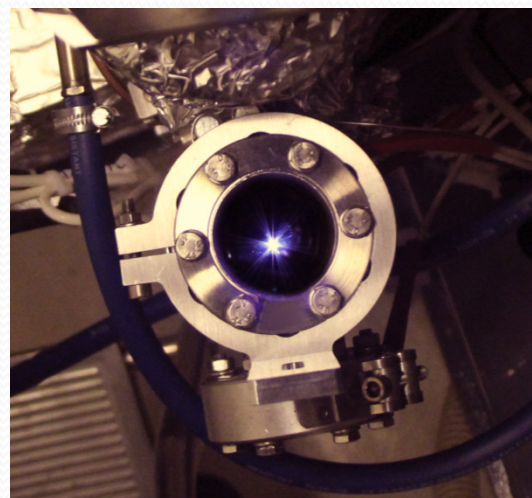
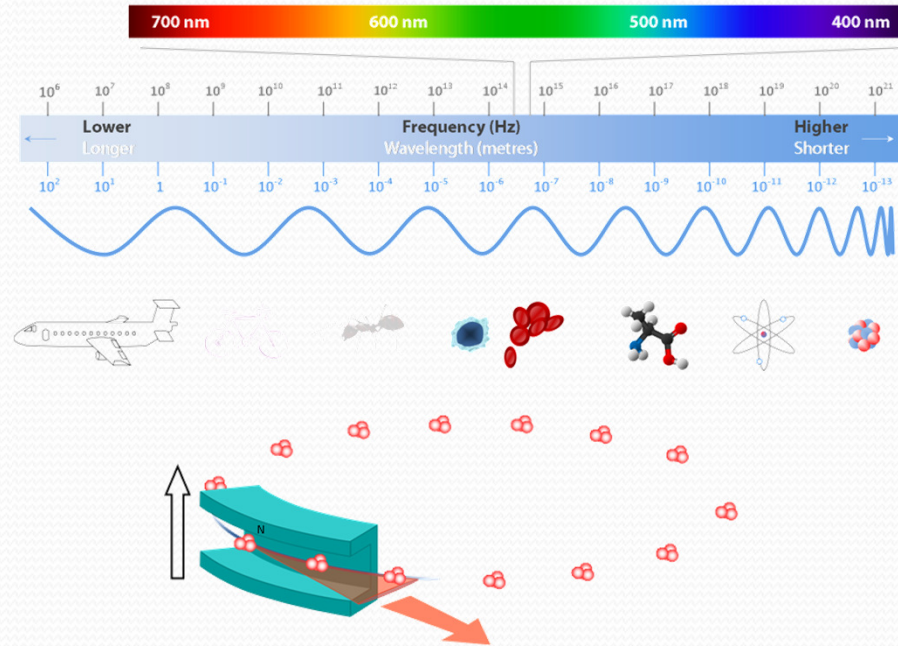
- DNA molekyler er et fascinerende komplekst system.
- Rigtigt mange elektroner og mange mulige tilstande
- Til vores studier bruger vi UV lys, og udnytter lysets polarisation samt at DNA er kiralt.
- Vi brug for en kraftig og tunebar UV kilde: Synkrotron stråling.
- Pt. bruger vi den gamle largerring ASTRID, men vi er ved at opbygge en ny avanceret kilde:

ASTRID₂

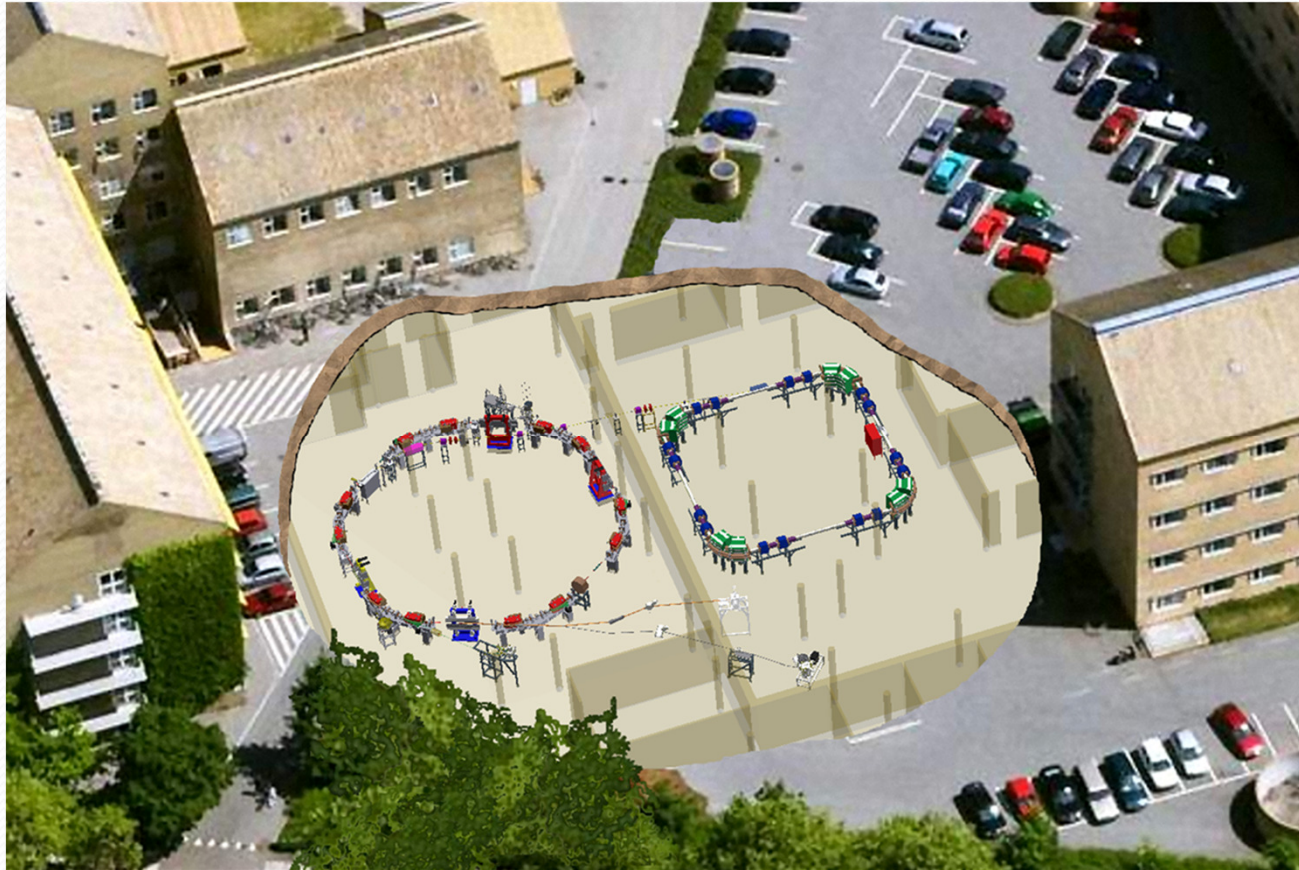


Synkrotron Stråling

- Elektromagnetisk stråling bruges på mange skalaer til at undersøge og måle verden.
- UV lys er velegnet til at undersøge molekyler som bl.a. DNA.
- Synkrotron stråling (SR) udsendes når ladede partikler accelereres: Her elektroner ved relativistiske energier.
- Lyset er meget intenst.

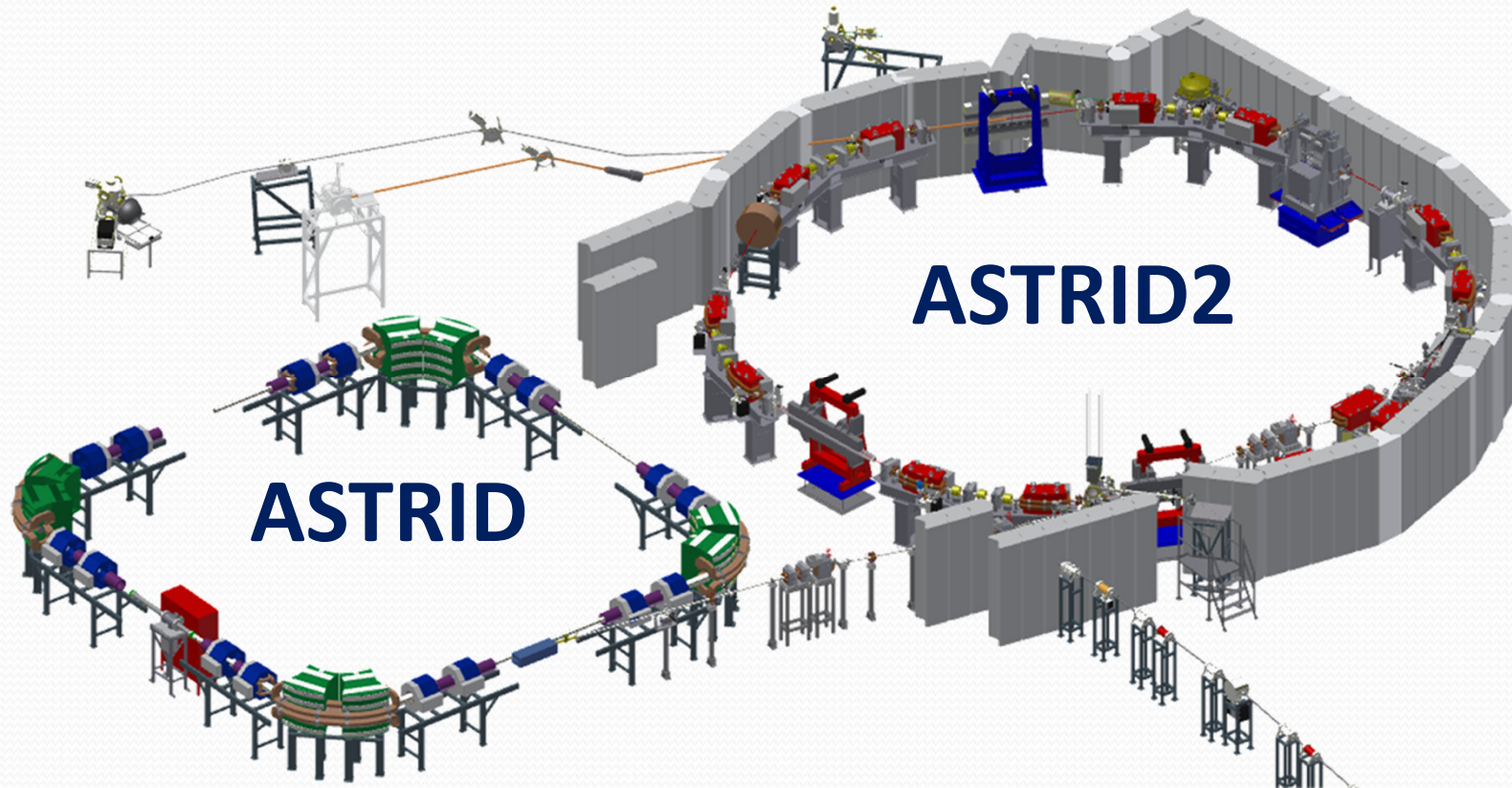


The ASTRID accelerator complex



The ASTRID and ASTRID2 complex is situated under the parking lot between physics and chemistry

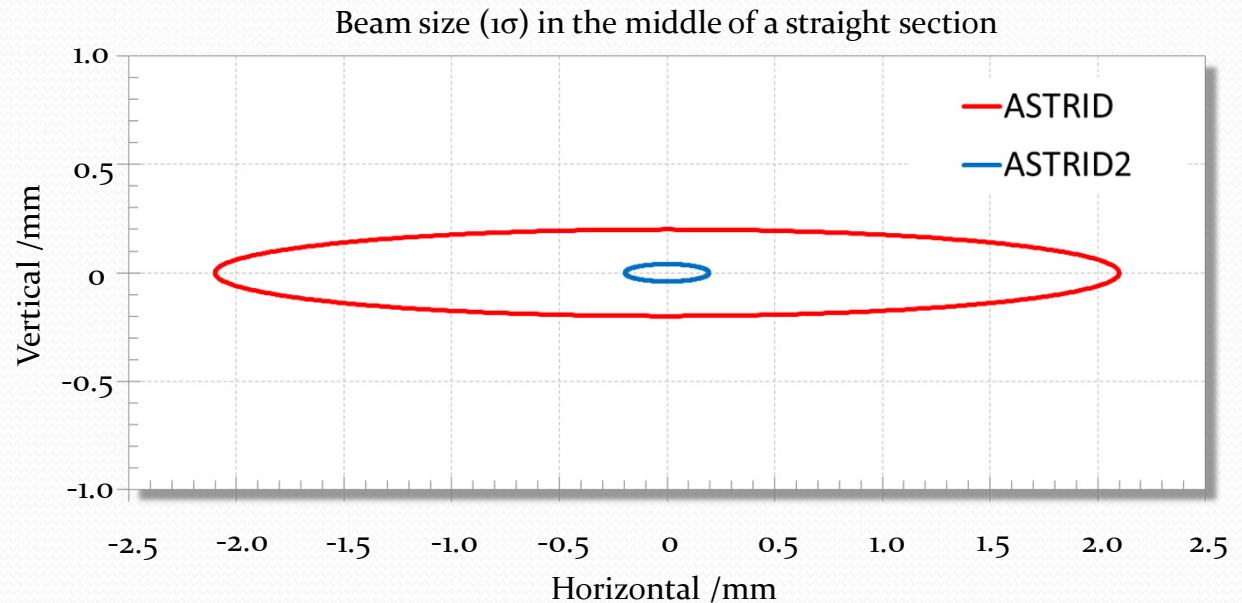
The ASTRID accelerator complex



ASTRID is a pre-accelerator allowing full energy injection into ASTRID₂ (top-up)

Hvorfor bygge en ny SR kilde?

- Tværsnittet af elektronstrålen er ca. 100 gange mindre.
- Dette er vigtigt for mange eksperimenter hvor en lille lysplet på prøven er vigtig.
- Gør det også muligt effektivt at bruge spejle til forme lyset og transportere det til prøven.



Mere lys med en mindre pletstørrelse:

Vi kalder lyset mere *Brilliant*

Åbner op for nye eksperimenter

f.eks. tidsafhængige studier af DNA's struktur.

Building ASTRID2



3rd January 2011:
Newly painted floor in empty hall.

Building ASTRID2



23rd March 2011:
Infrastructure ready.

Building ASTRID2



28th June 2011:
First girder delivered

Building ASTRID2



20th July 2011:
All girder installed

Building ASTRID2



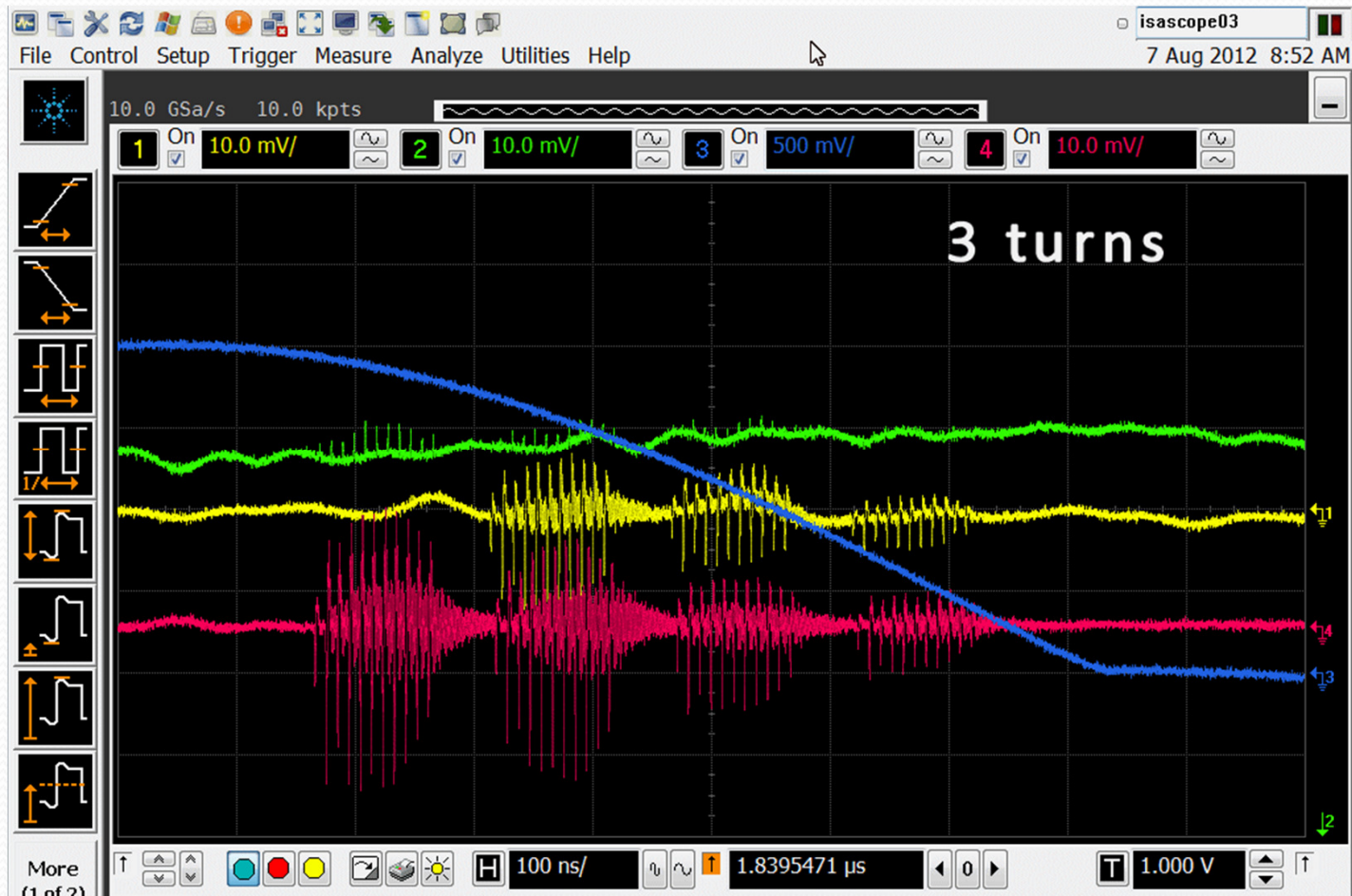
8th March 2012:
Most of the ring under vacuum

Building ASTRID2



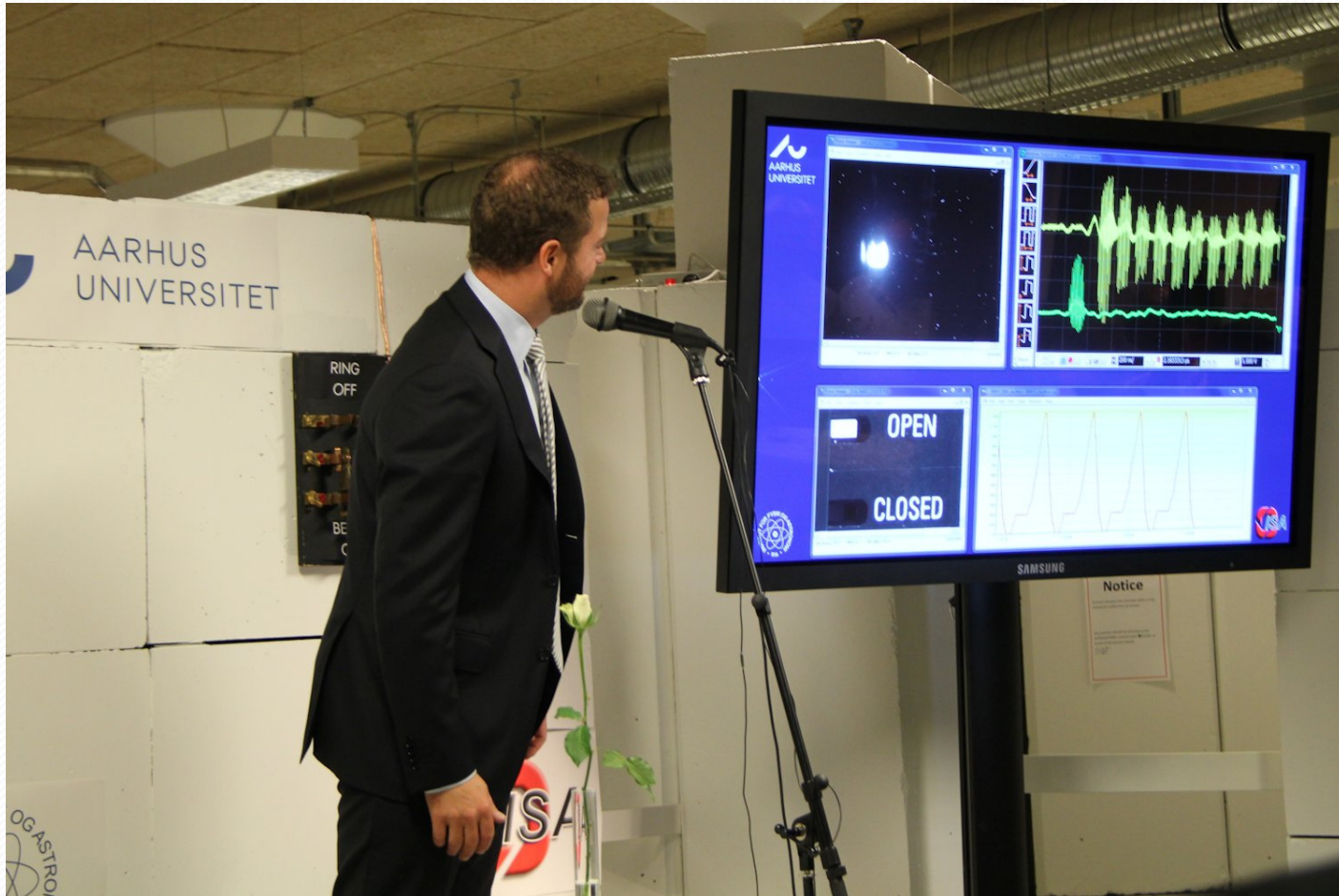
11th May 2012:
RF cavity in place and concrete wall build

Building ASTRID2



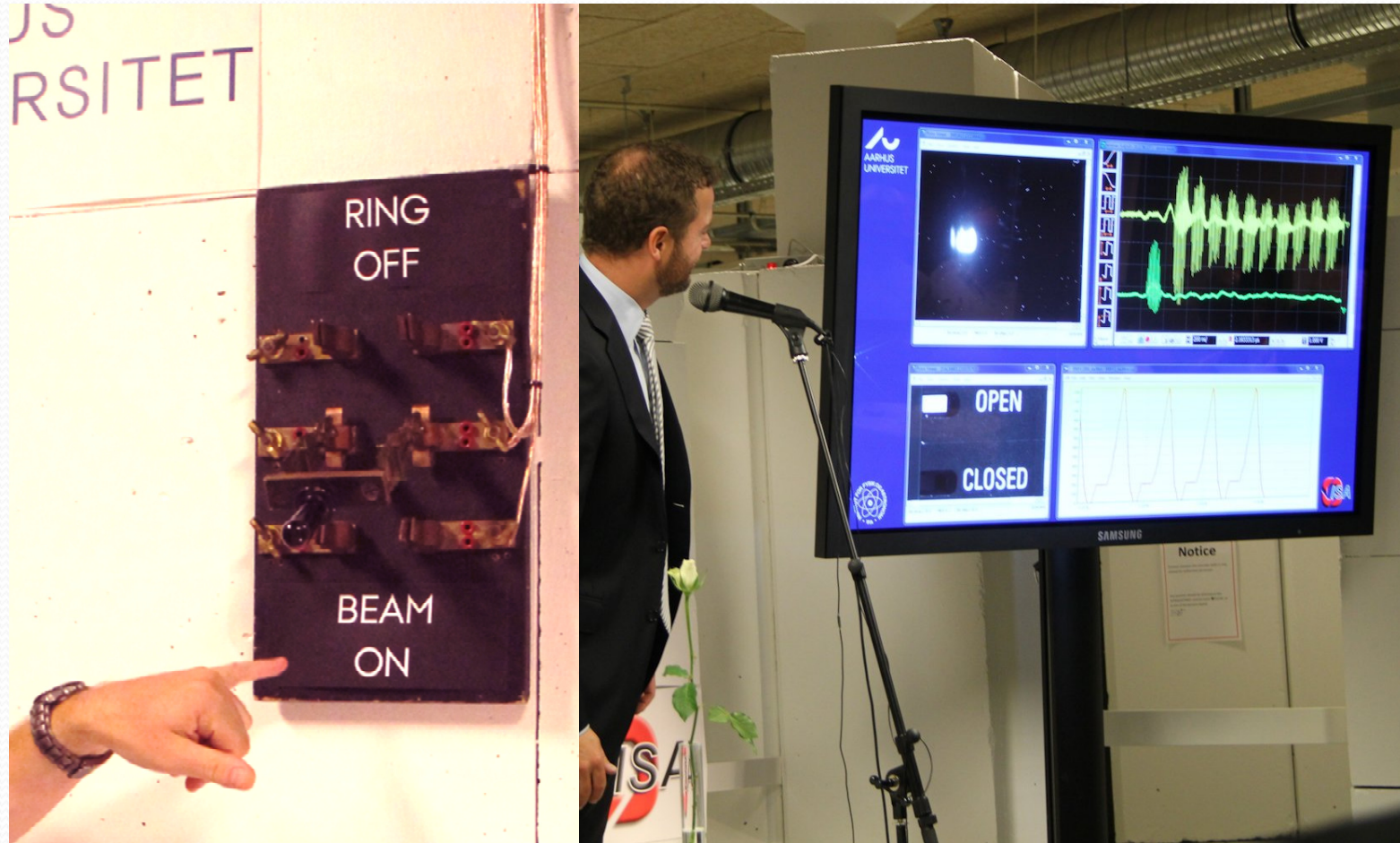
7th August 2012:
First multi turns of beam in ASTRID₂ (no RF)

Building ASTRID2



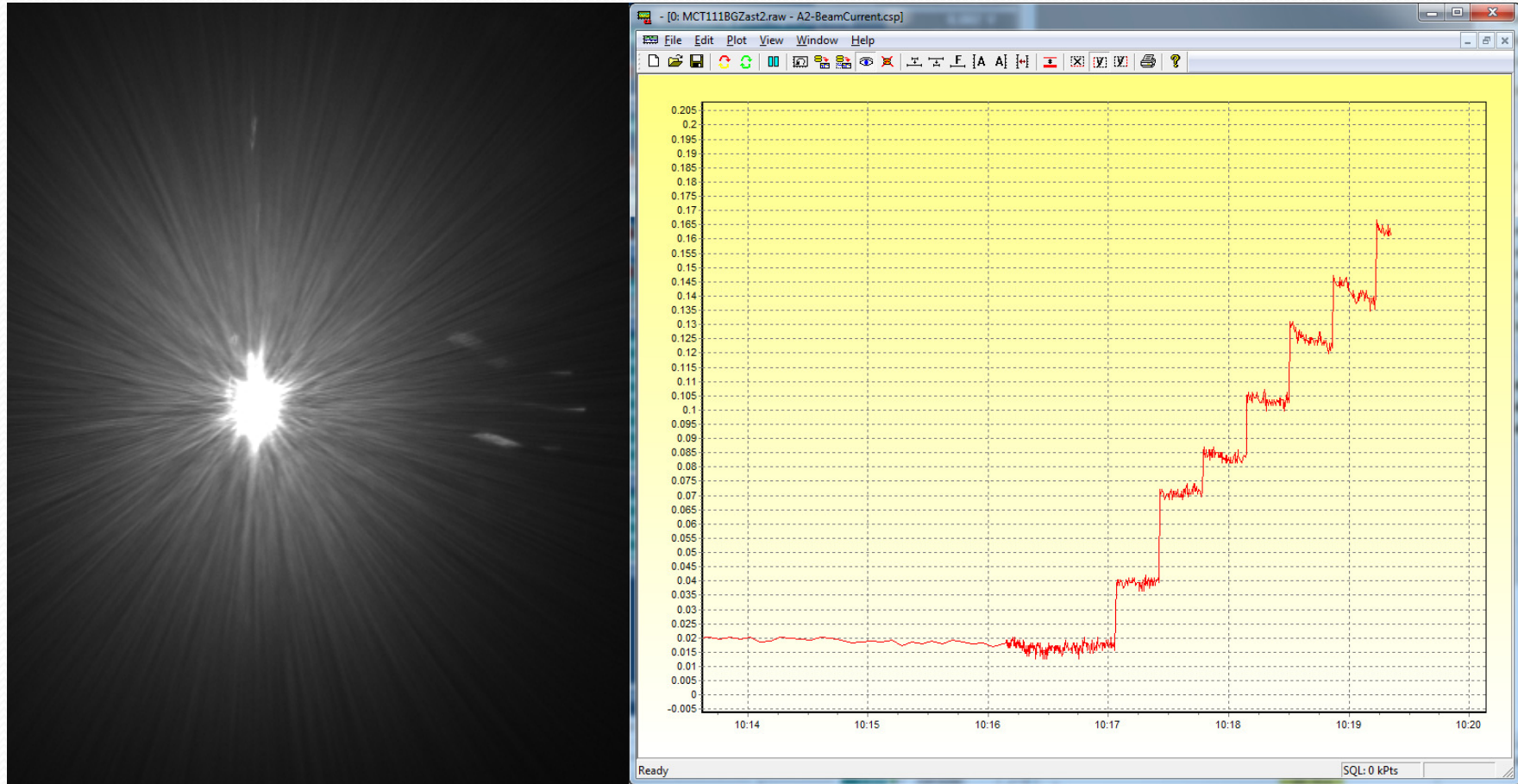
10th September 2012:
Official opening by the Danish Minister for Research,
Innovation and Higher Education

Building ASTRID2



10th September 2012:
Official opening by the Danish Minister for Research,
Innovation and Higher Education

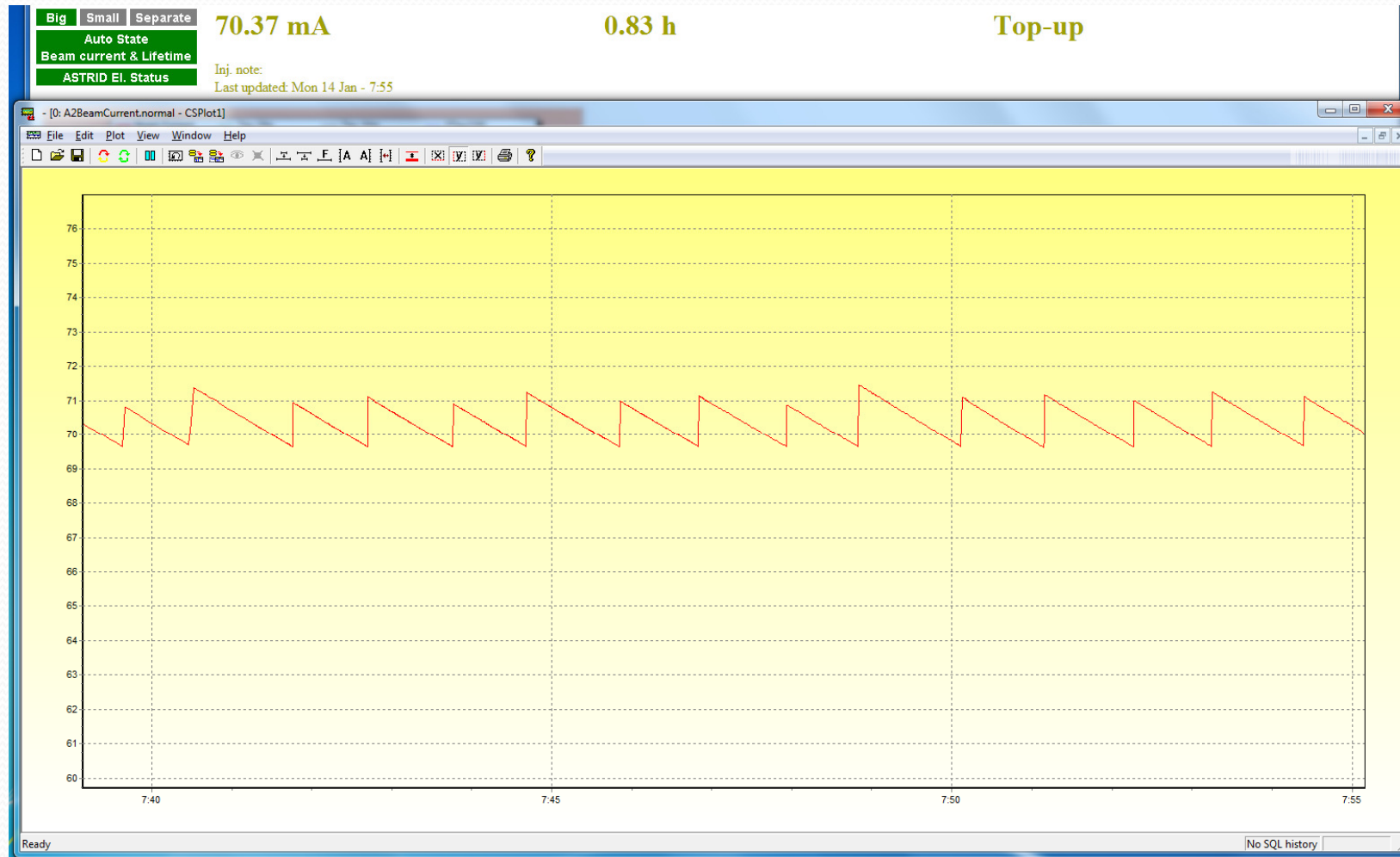
We have a stored beam !!!



The first beam was stored Friday 2nd November 2012

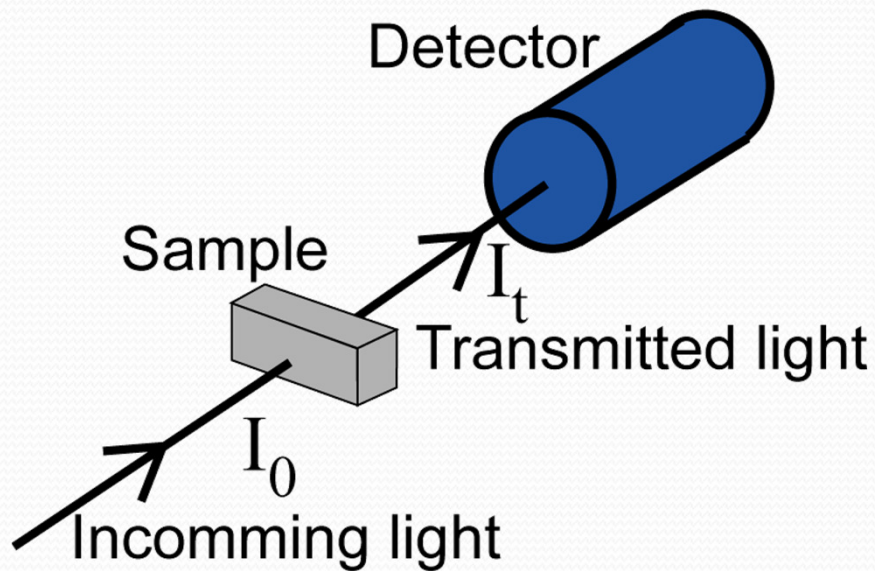
Only one day and a morning after commissioning RF

We have a stored beam !!!



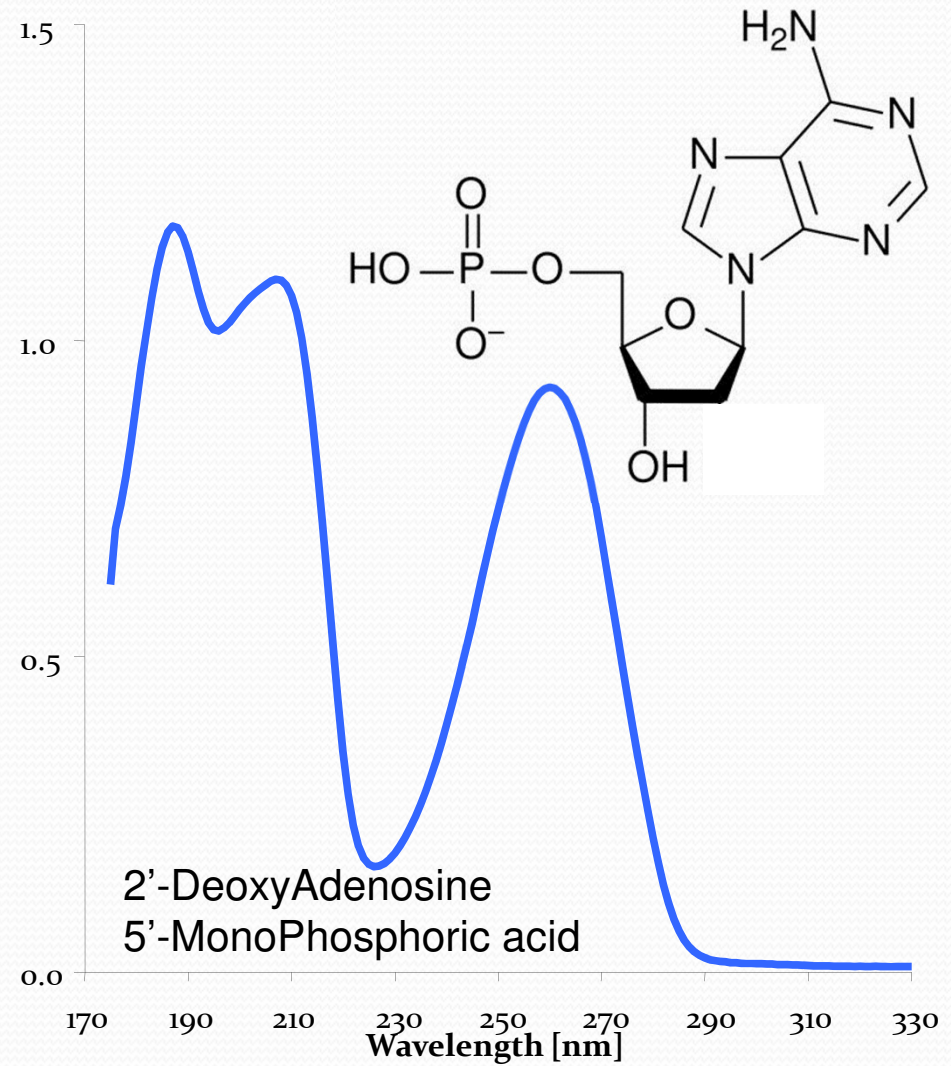
Top-up mode (14th January 2013)

Absorption Spectroscopy

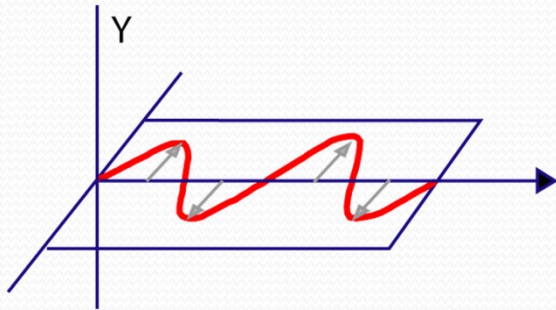


Absorbance:

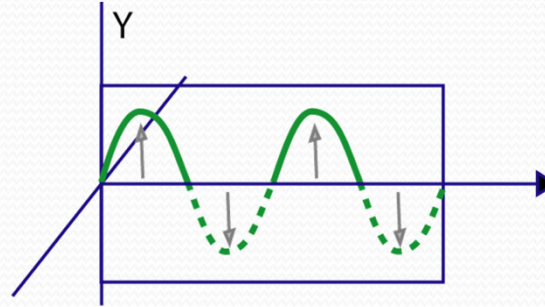
$$A = \log(I_0/I_t)$$



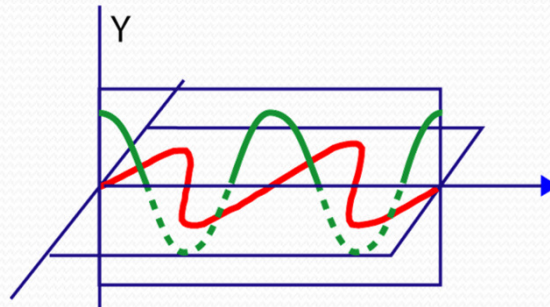
Polarized light



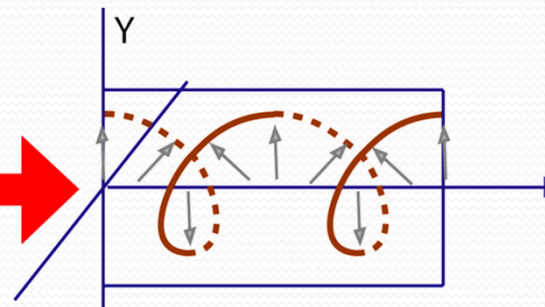
Horizontally pol.



Vertically pol.

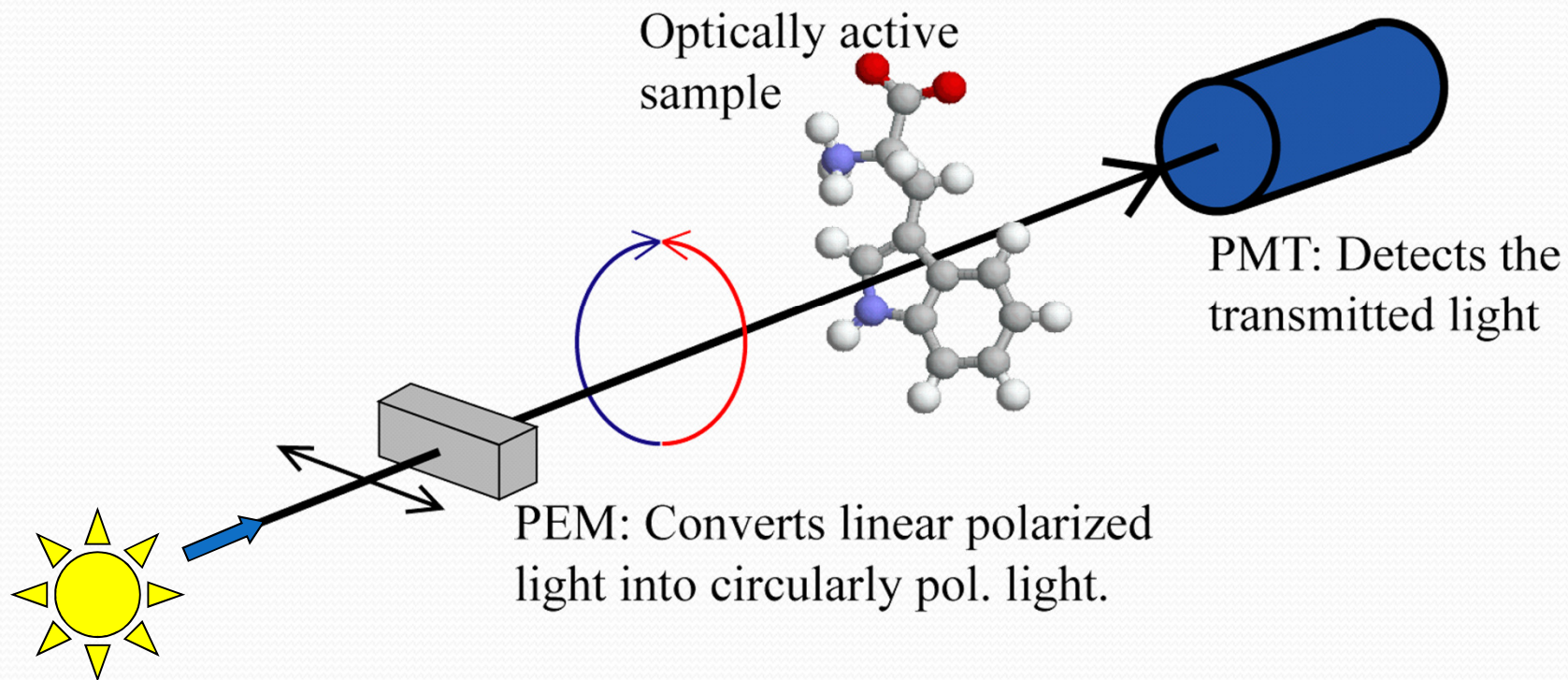


Sum of two
plane pol.



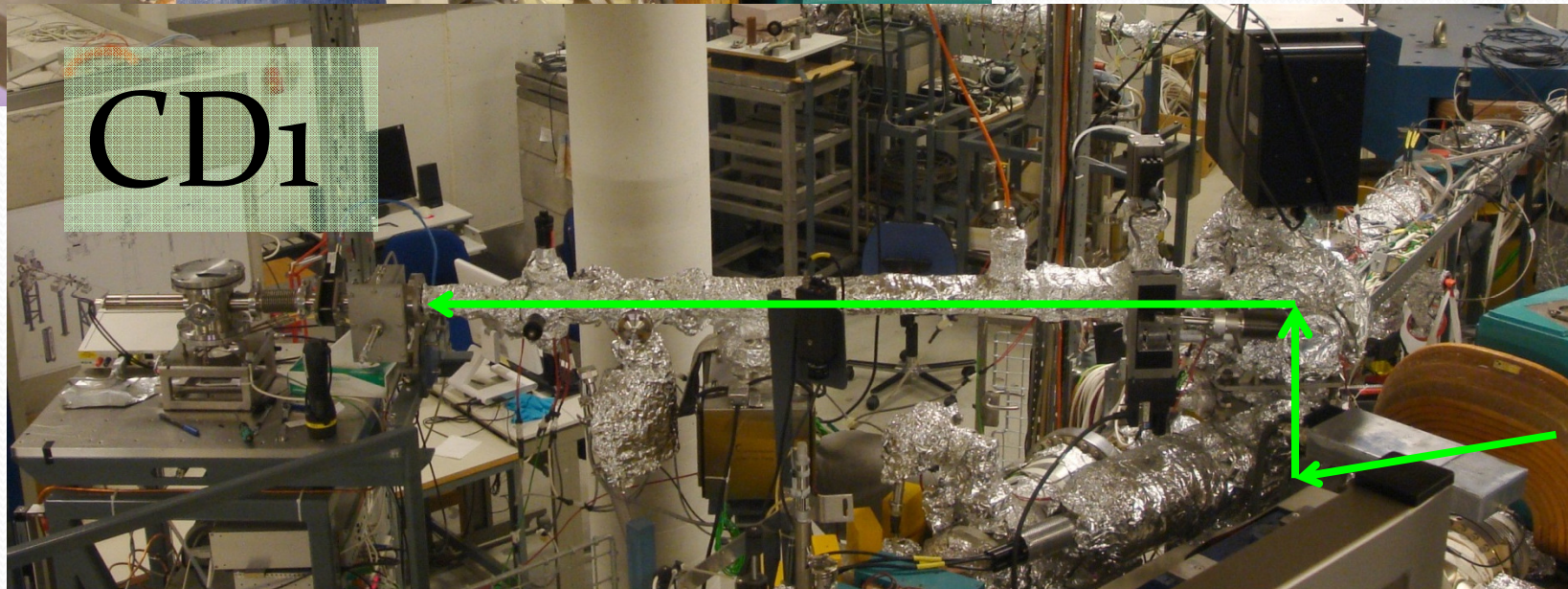
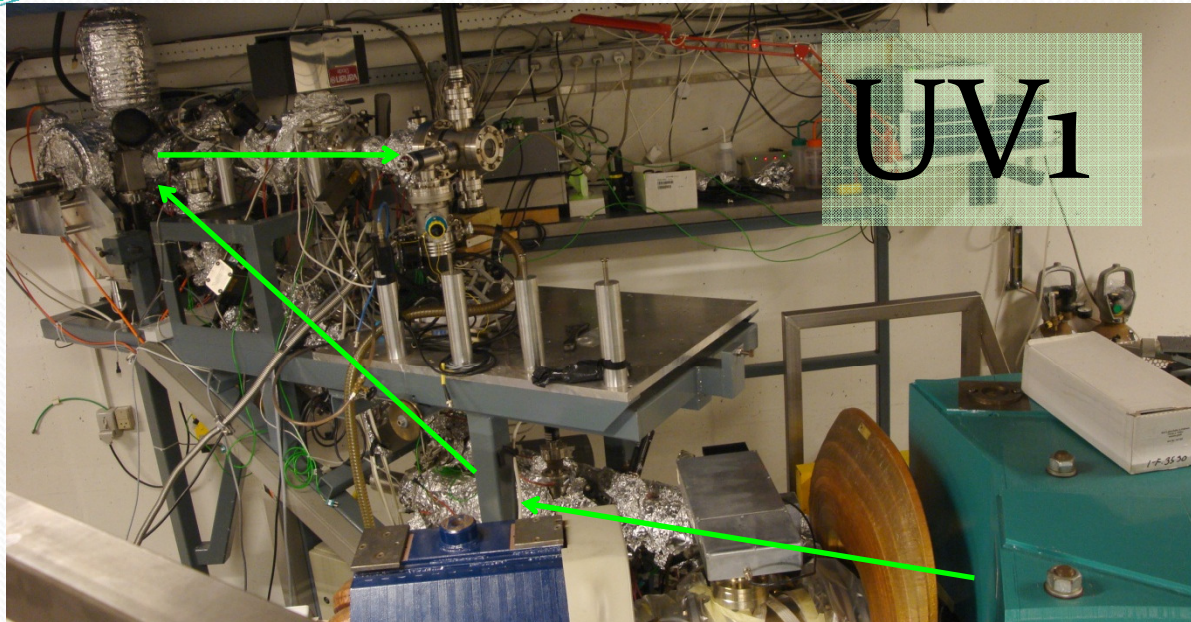
Circularly pol.

Circular Dichroism

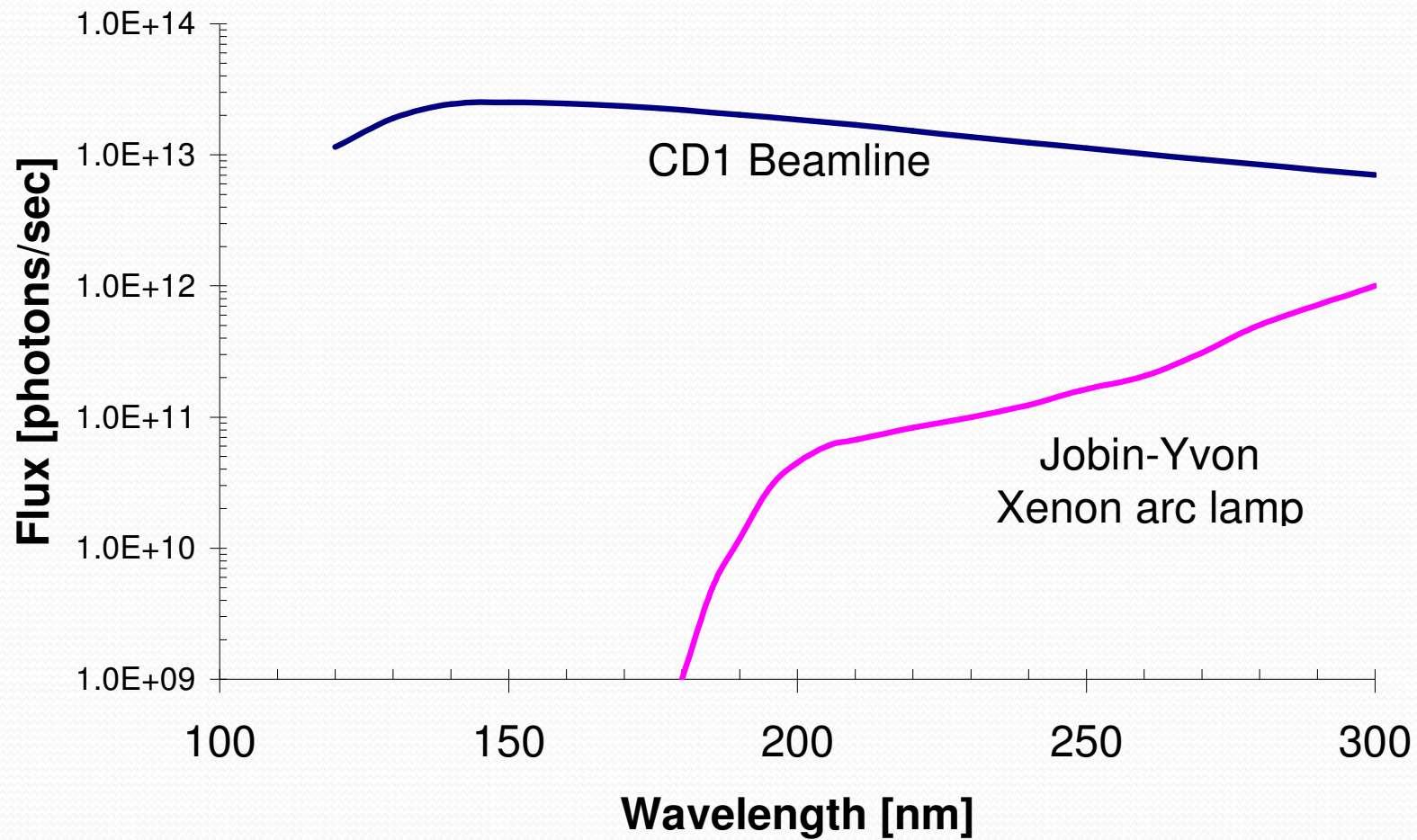


The CD signal: $CD = A_L - A_R$

The Ultra Violet beamlines

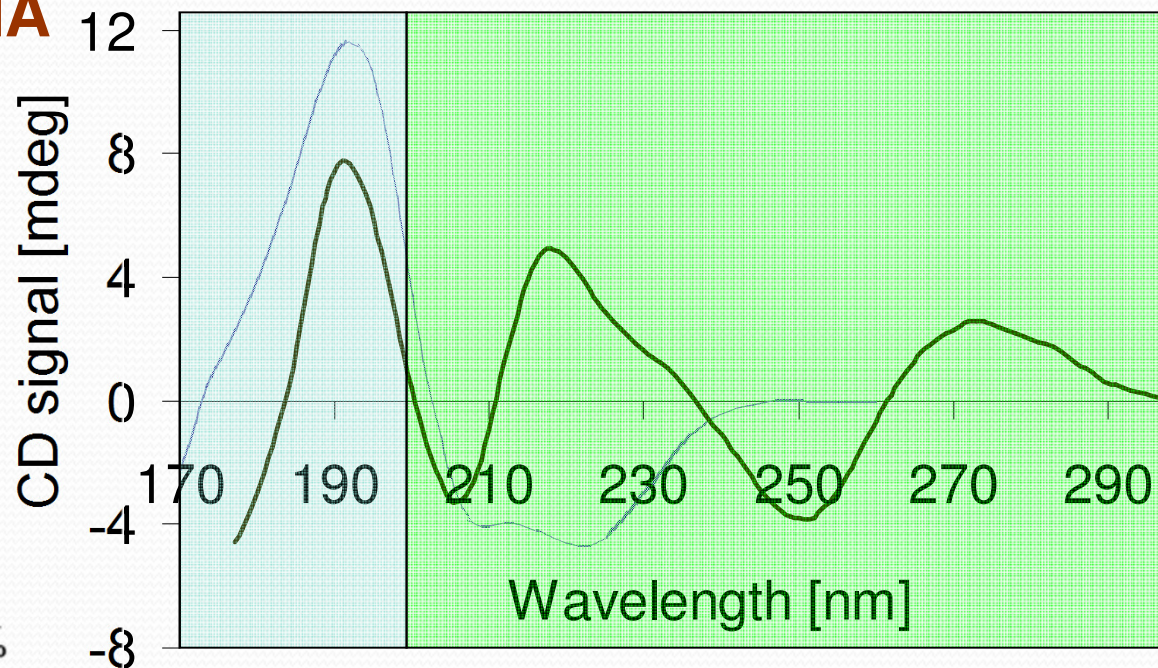
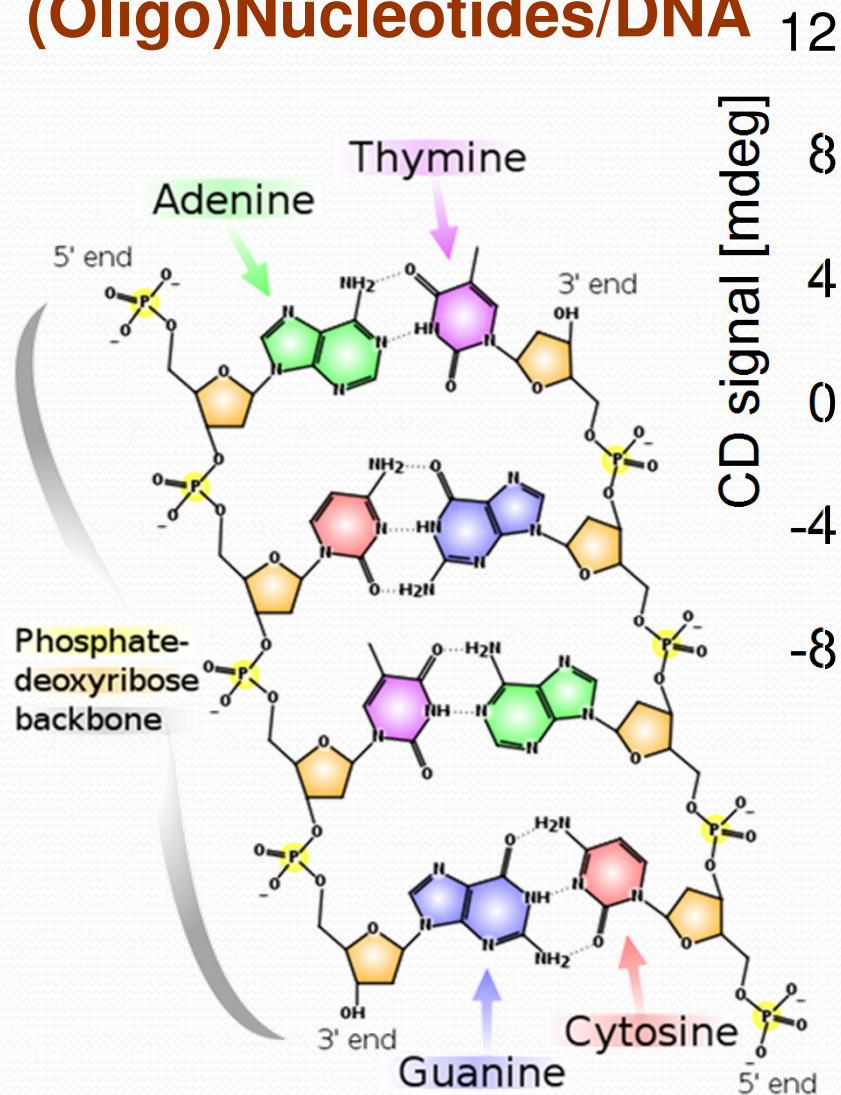


Light Sources



SRCD: Why do it

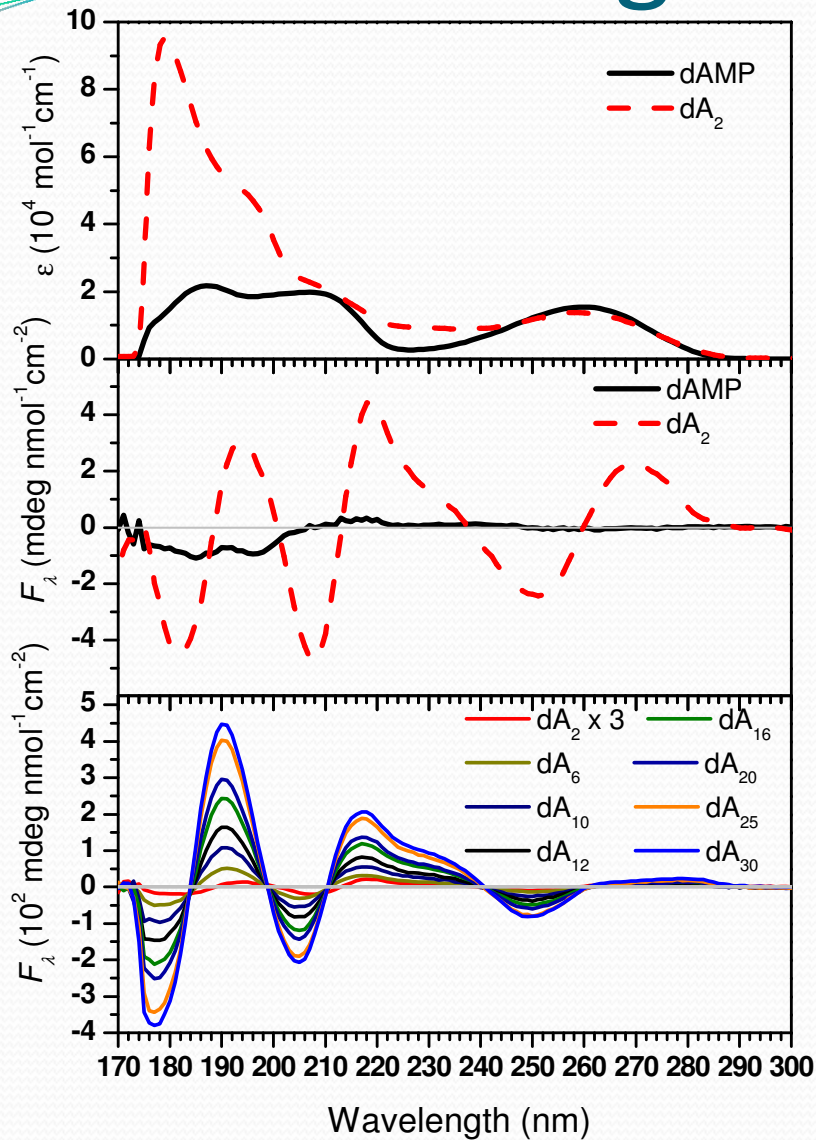
(Oligo)Nucleotides/DNA



Strong CD signal below 300 nm:
Are data below
200 nm really important?

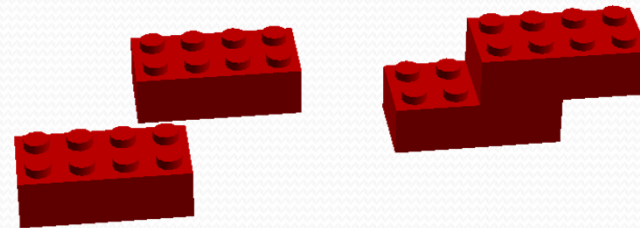
YES!!

SRCD on Oligo-nucleotides



Single strands of adenine nucleotides

dAMP vs. dA₂



Circular Dichroism:
Strong coupling between bases

$$dA_n \quad n = 2 - 30$$

The signal at 190 nm:
Doesn't increase linearly with n
(for small n)

SRCO on Oligo-nucleotides

The signal at 190 nm: Doesn't increase linearly with n (for small n)

Make a model:

a_1, a_2, a_3, \dots are “coupling” terms

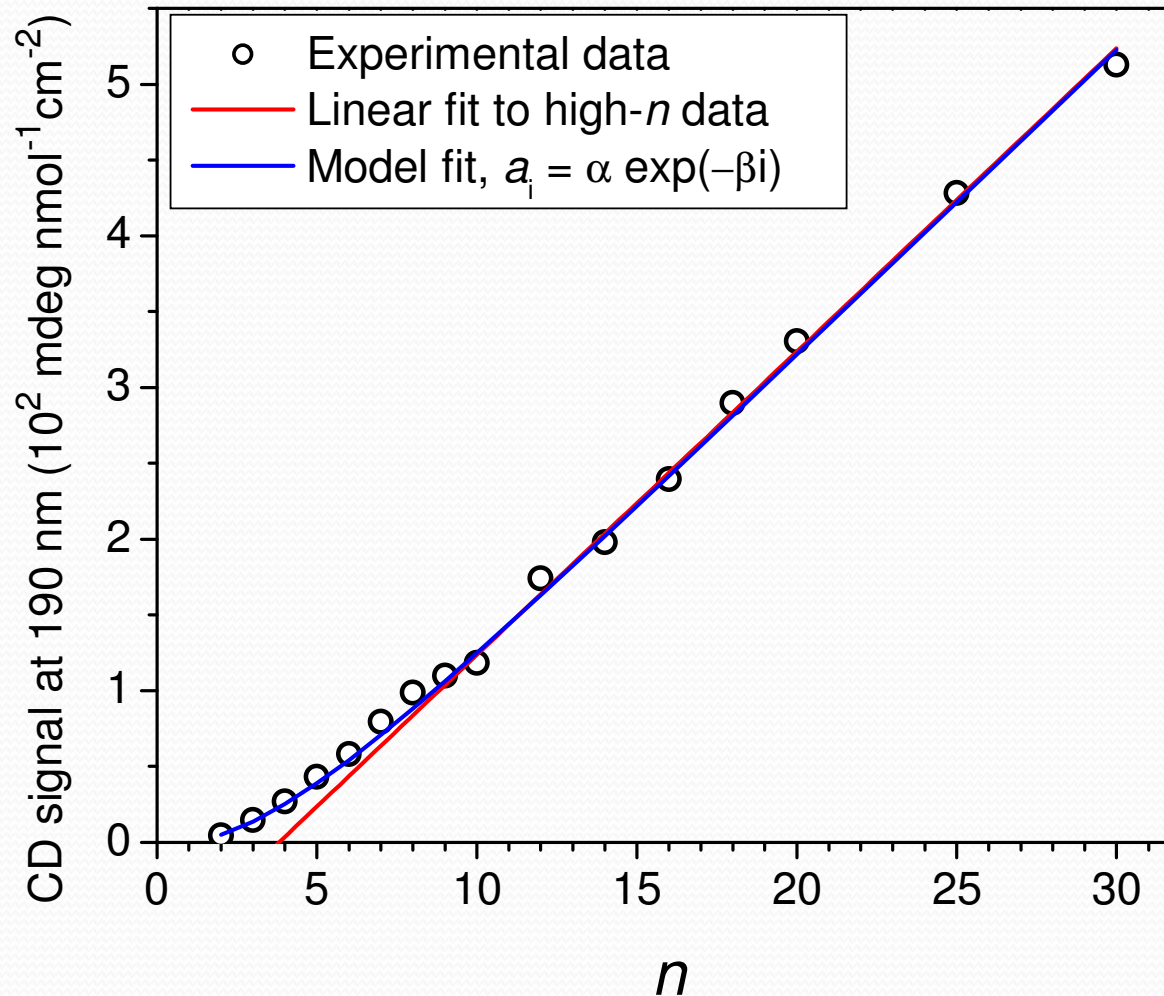
e.g. $F_\lambda(4) = a_3 + 2a_2 + 3a_1$

In general: $F_\lambda(n) = \sum_{i=1}^n (n-i)a_i$

Where $a_i = \alpha \exp(-\beta i d)$, $d = 3.4 \text{ \AA}$

SRCO on Oligo-nucleotides

CD signal
190 nm

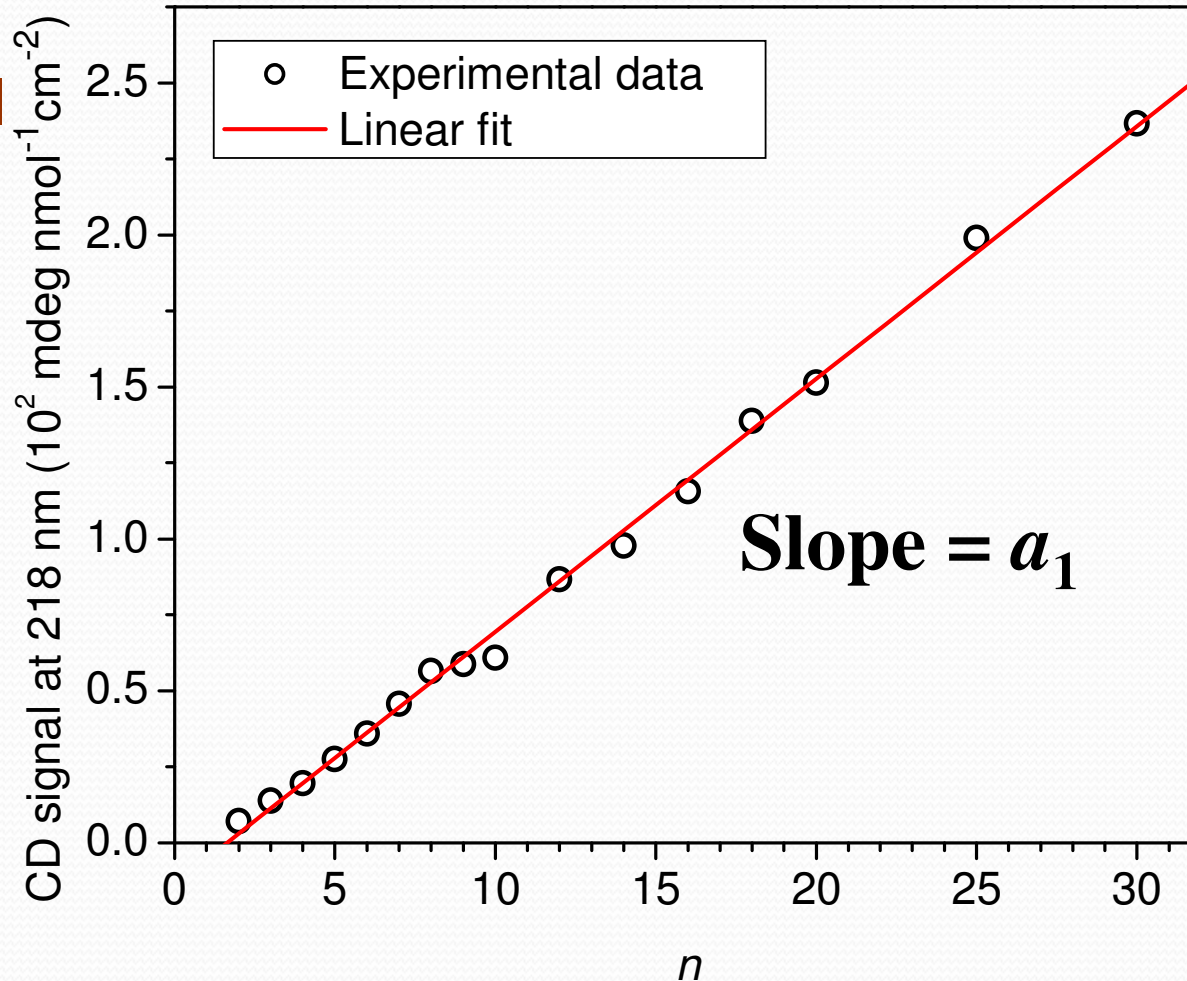


At least *eight* nucleobases couple.

Nearest neighbour coupling (a_1) is only about 24%

SRCD on Oligo-nucleotides

CD signal
218 nm



Only *two* adenine bases couple

SRCF on Oligo-nucleotides

Conclusion:

Electronic coupling between stacked adenine bases depends strongly on the excitation energy (wavelength)

➔ Below 200 nm: At least eight adenine bases couple

➔ Above 200 nm: Only two adenine bases couple

Electronic coupling between nucleobases impacts:

- Excitation energy is spread over a large spatial region

➔ Self-protection mechanism of DNA:
less prone to UV or VUV damage

- DNA as a conducting nanowire

Hvad kan vi lave ved ASTRID2?

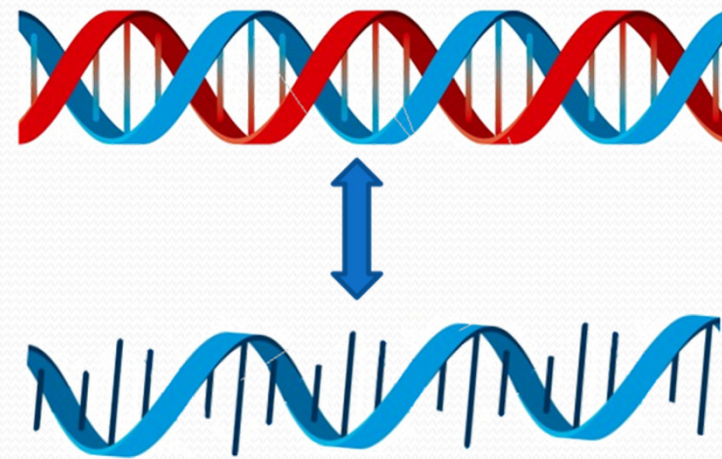
Tidsopløste eksperimenter

Med en langt mere intens UV lyskilde kan vi følge ændringer i struktur.

F.eks. enkeltstreng til dobbeltstreng DNA

ASTRID Tidsskala: Sekunder til minutter

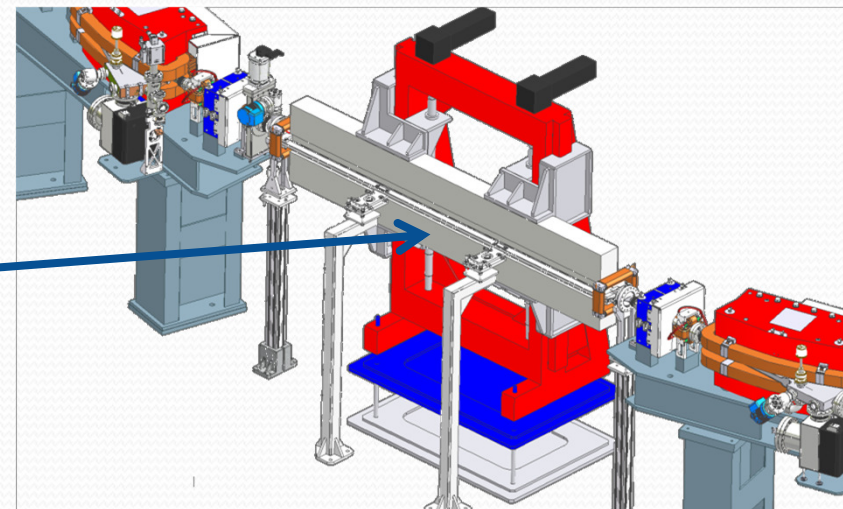
ASTRID₂ Tidsskala: Millisekunder



Muligt med en ny og kraftig 2.4 m lang magnetisk struktur:

Undulator

Er netop leveret fra Italien...



Hvad kan vi lave ved ASTRID2?

Tidsopløste eksperimenter

Med en langt mere intens UV lyskilde kan vi følge ændringer i struktur.

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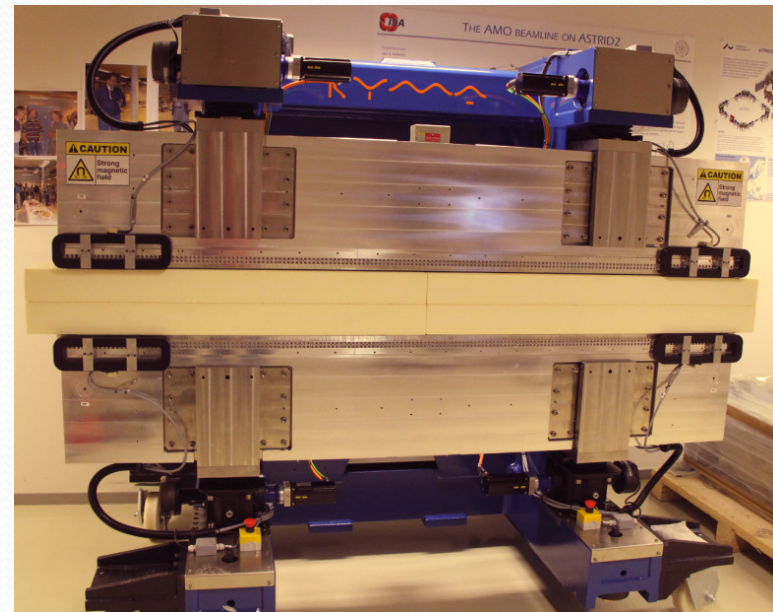
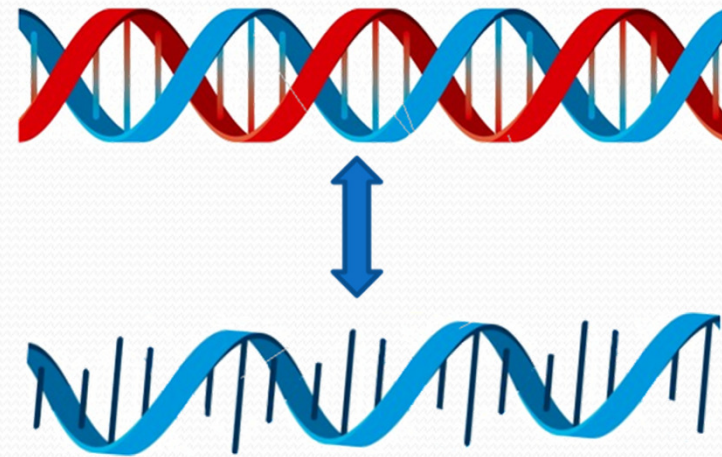
ASTRID Tidsskala: *Sekunder til minutter*

ASTRID₂ Tidsskala: *Millisekunder*

Muligt med en ny og kraftig 2.4 m lang magnetisk struktur:

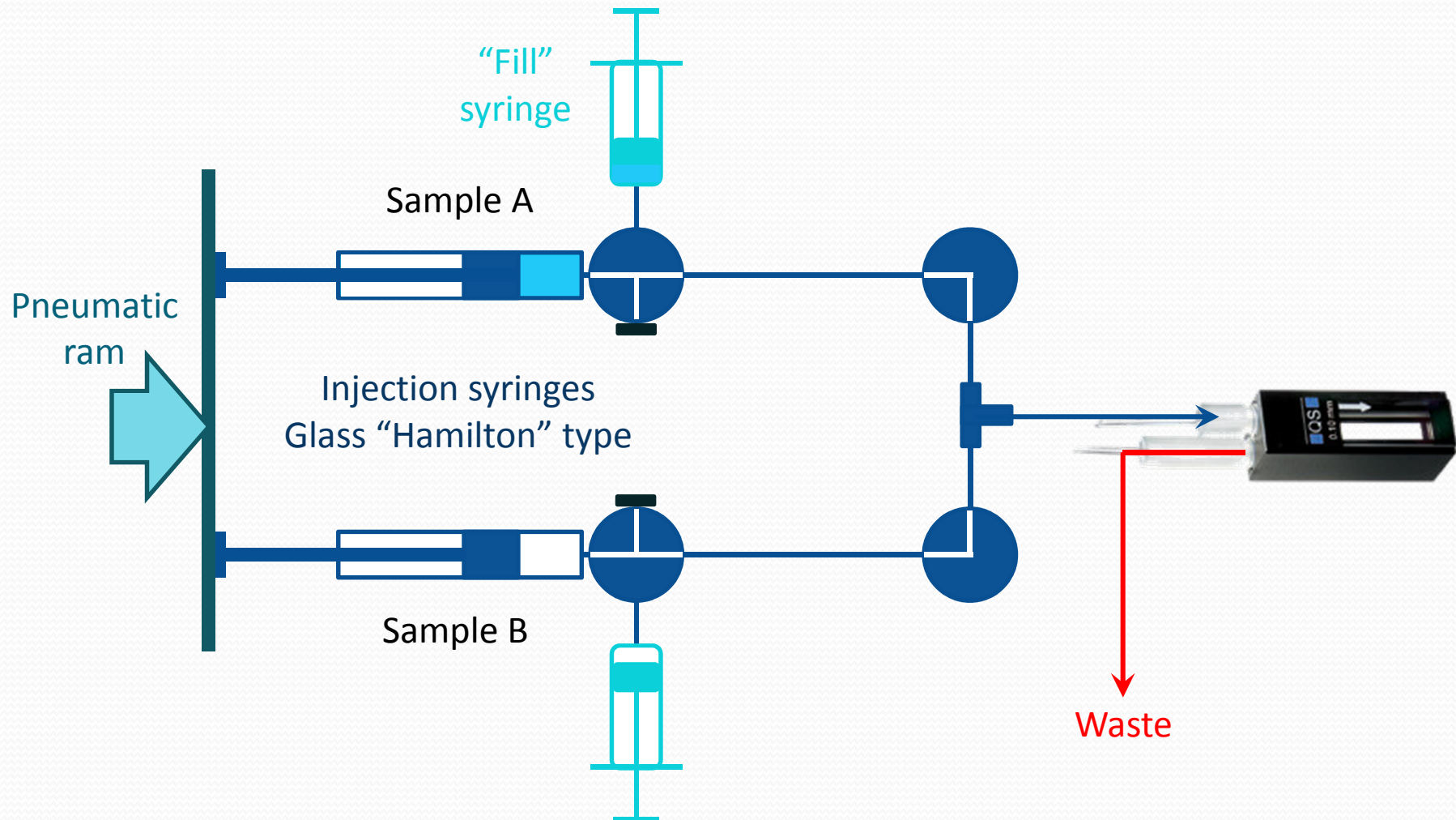
Undulator

Er netop leveret fra Italien...



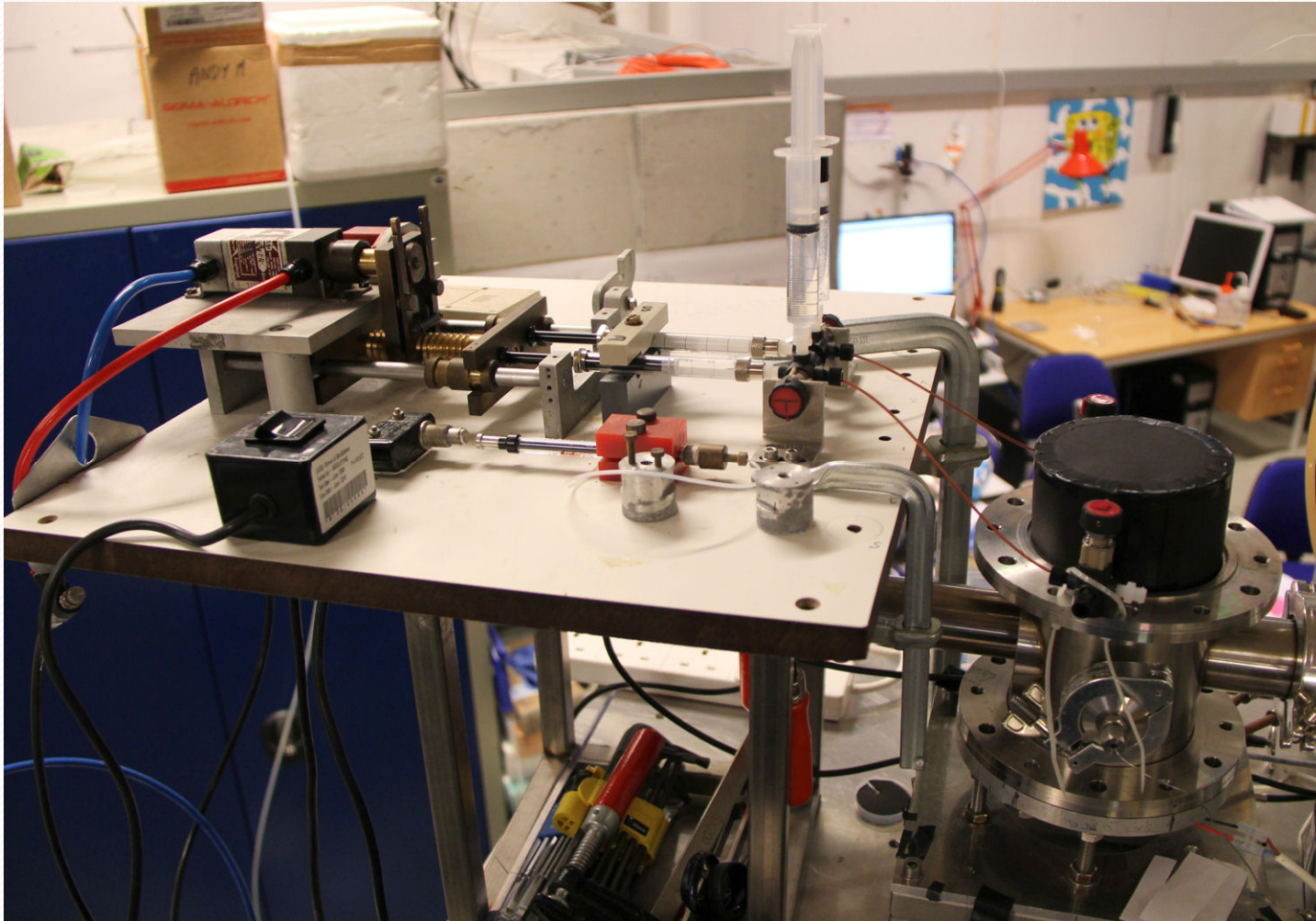
Hvad kan vi lave ved ASTRID2?

Blanding af DNA enkelt strenge med salt: Mixer



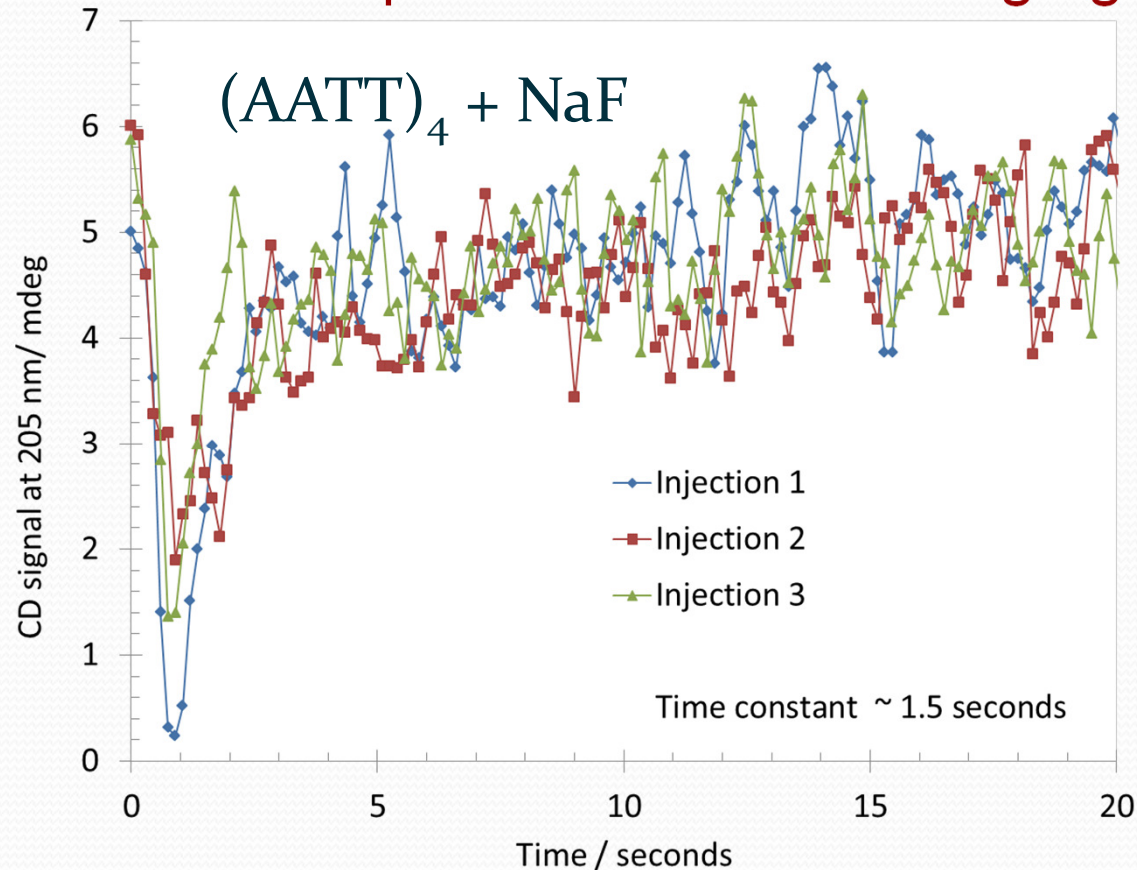
Hvad kan vi lave ved ASTRID2?

Udvikling af mixer (George Gearløs)



Hvad kan vi lave ved ASTRID2?

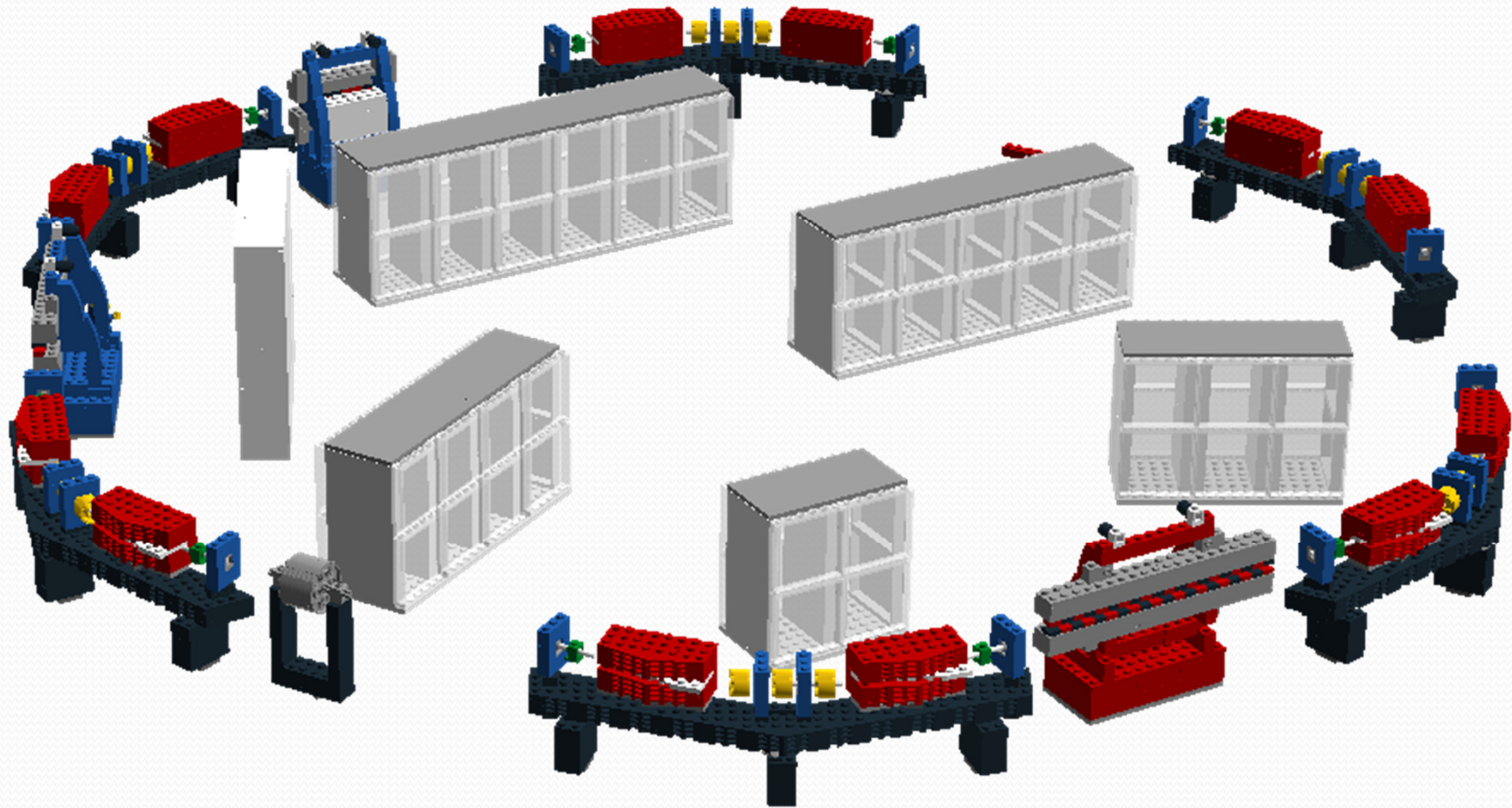
Første test: Selv komplementær DNA streng og salt



Hurtig reaktion:
Lidt støjet:

Overstået på få sekunder...
Bedre UV kilde / ASTRID2

Kom og besøg ASTRID2



Courtesy: Dr. N.C. Jones