Curvature Wavefront Sensor Arbitrary Waveform Generator

Kenyan Kawauchi

Subaru Telescope (NAOJ)
Mentor: Stephen Colley

Subaru Adaptive Optics

Without AO

Earth's atmosphere distorts light

↓

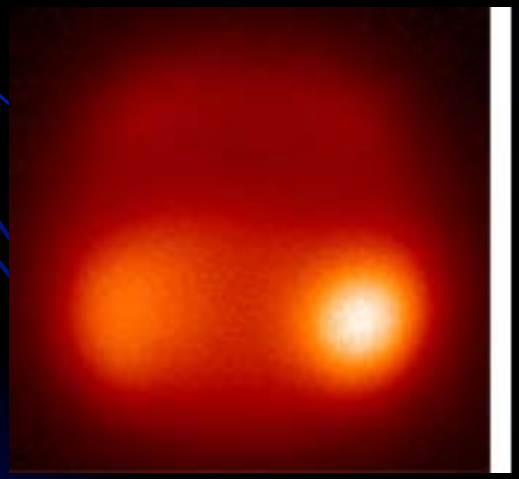
Telescope images blurred

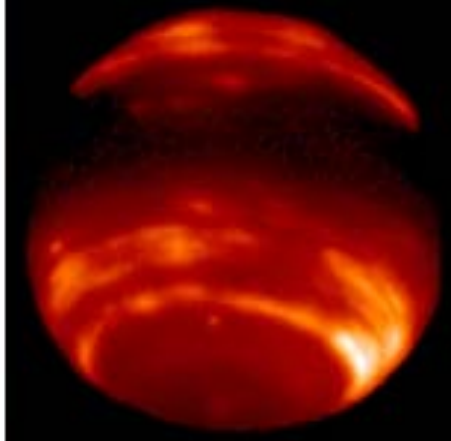
With AO

Removes effects of atmospheric distortion

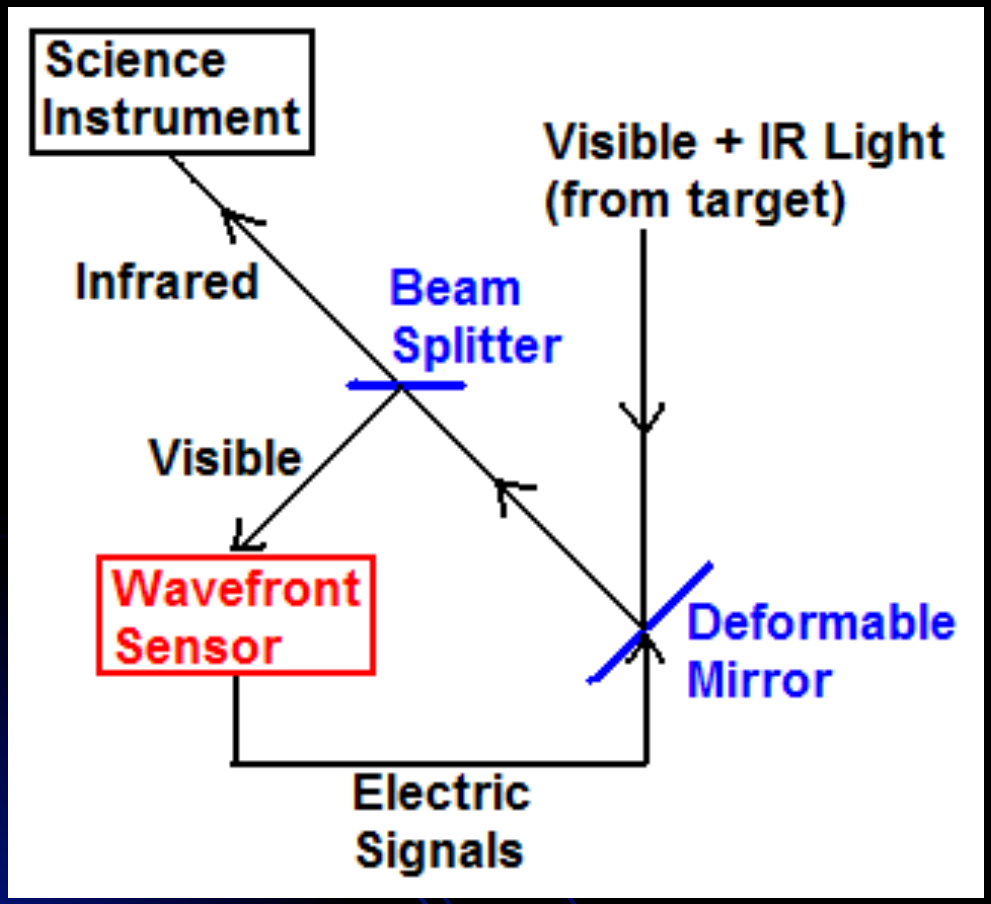
↓

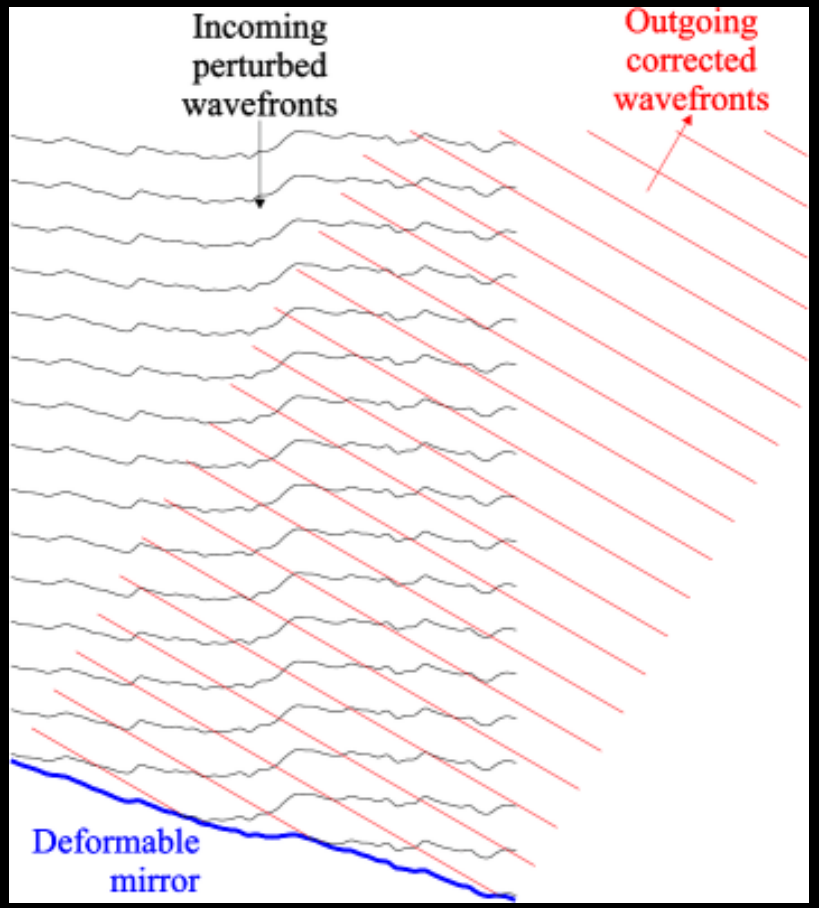
Image resolution improved





AO System Components





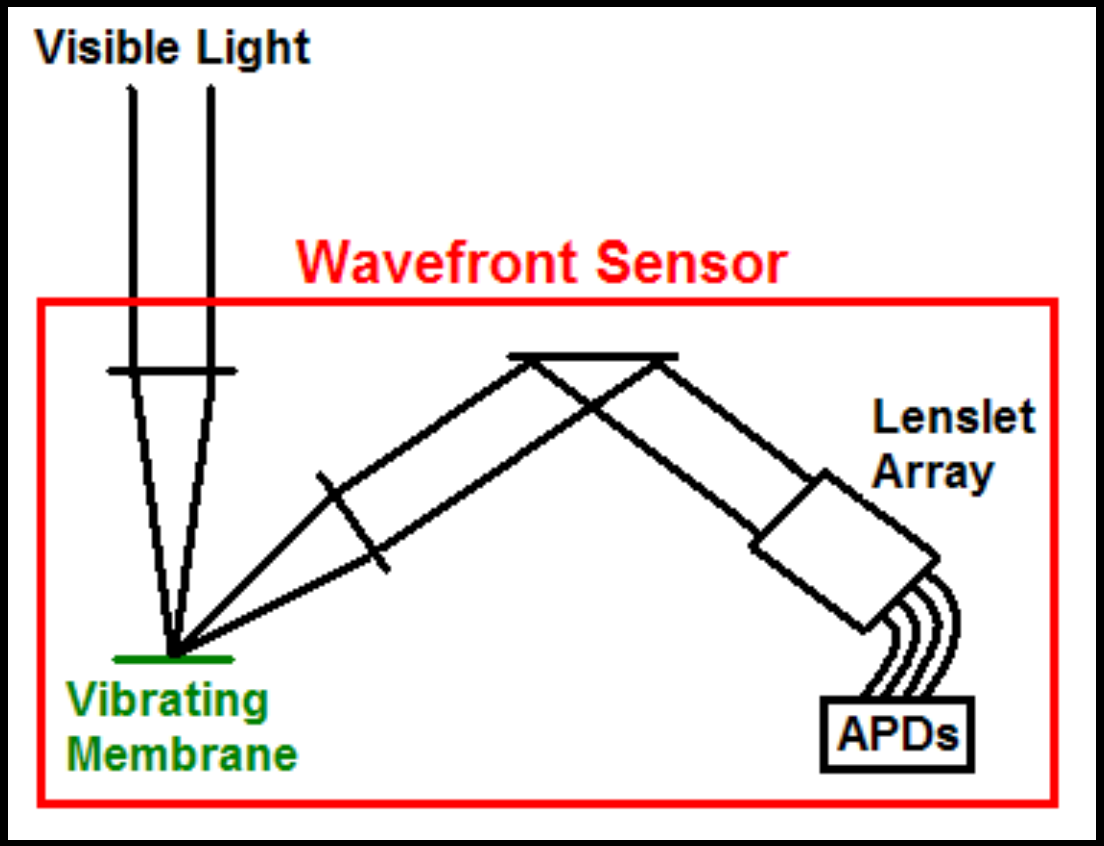
Wavefront Sensor

Visible light reflects off ***one side*** of membrane

APDs count photons in each lenslet

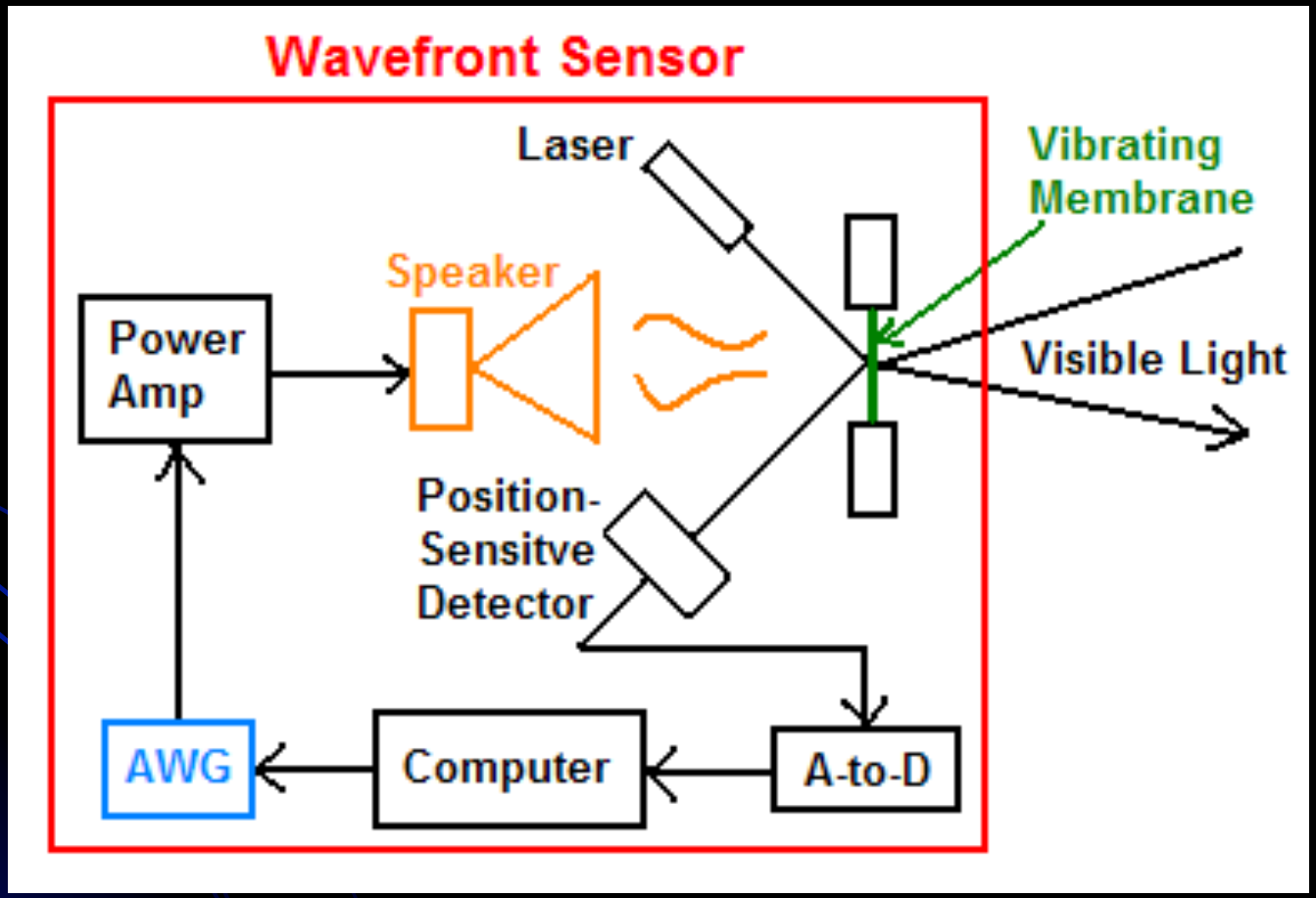
Measure light intensity

Calculate wavefront phase shift

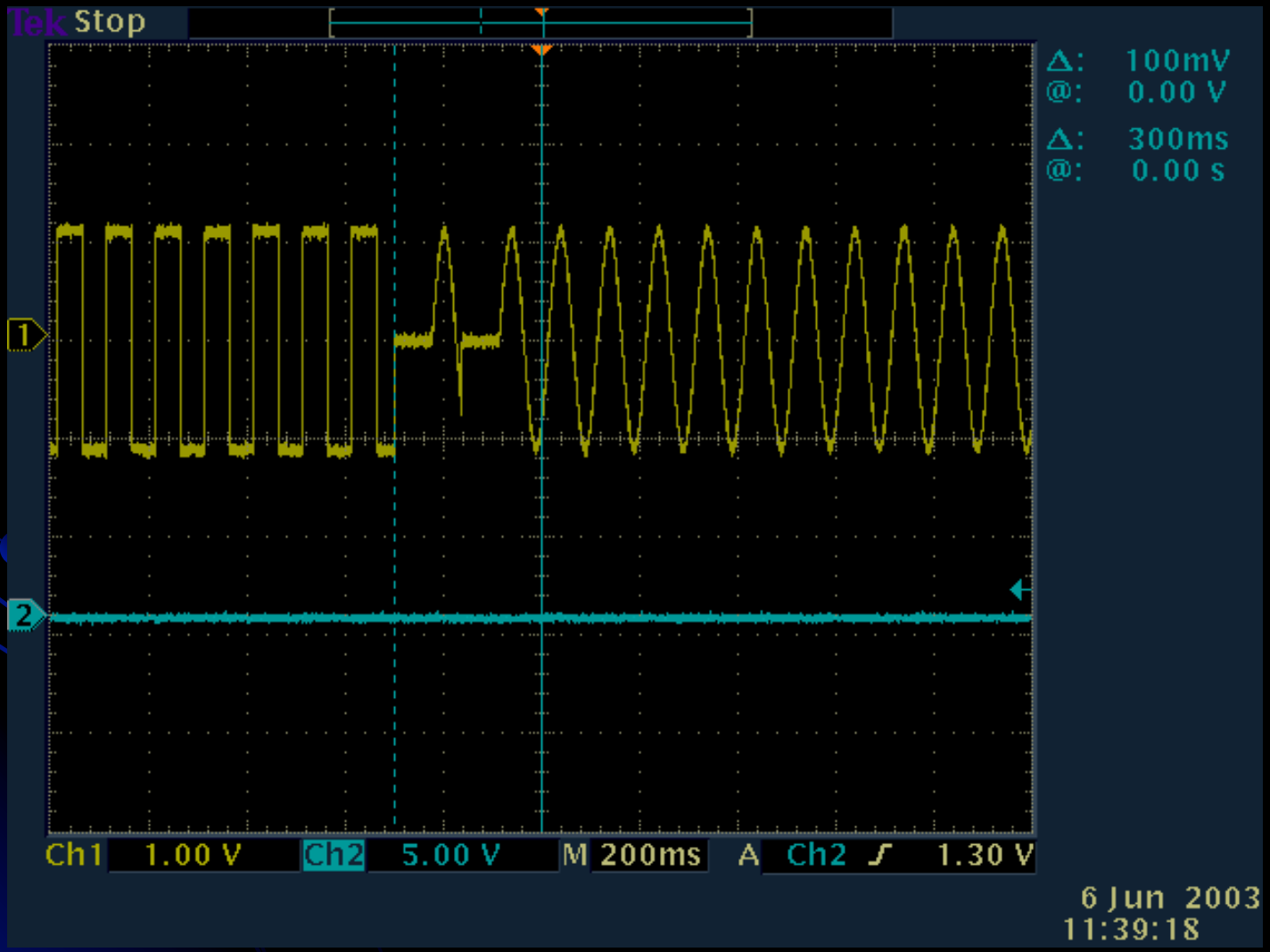


What vibrates membrane?

Other side of membrane

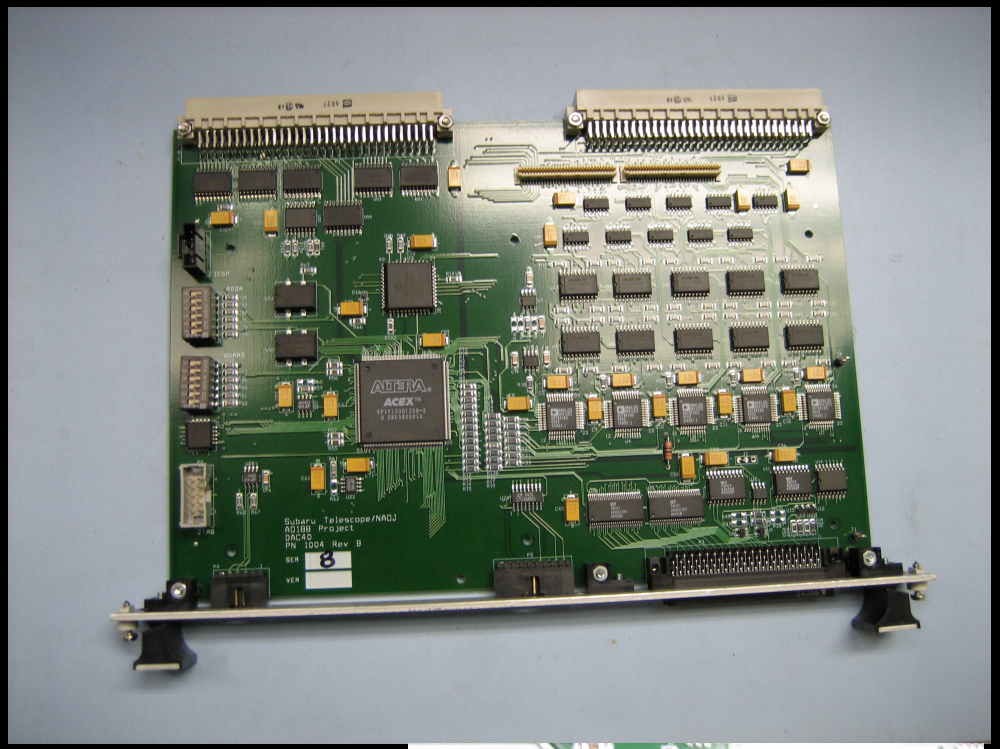


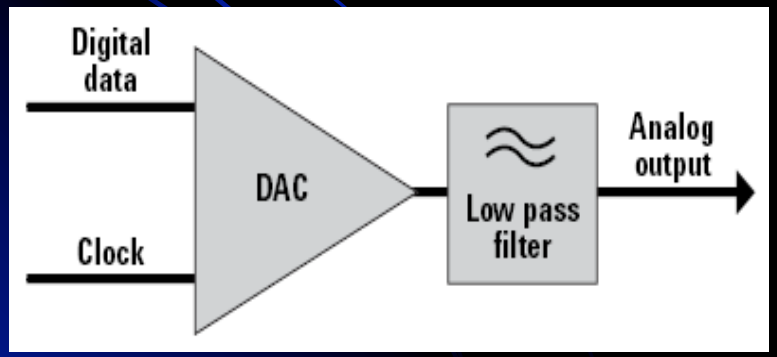
Problem

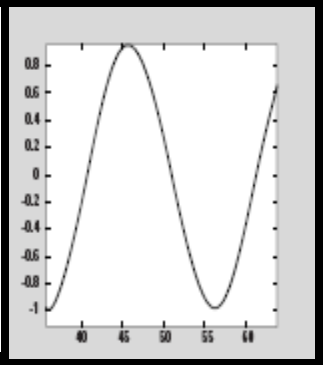

Tek Stop
Δ: 100mV
@: 0.00 V
Δ: 300ms
@: 0.00 s
1
2
Ch1 1.00 V
Ch2 5.00 V
M 200ms
A Ch2 1.30 V
6 Jun 2003
11:39:18

Solution

- Design your own AWG!
- Use DAC40 board
  - Field Programmable Gate Array (FPGA)
  - Digital-to-Analog Converters (DACs)

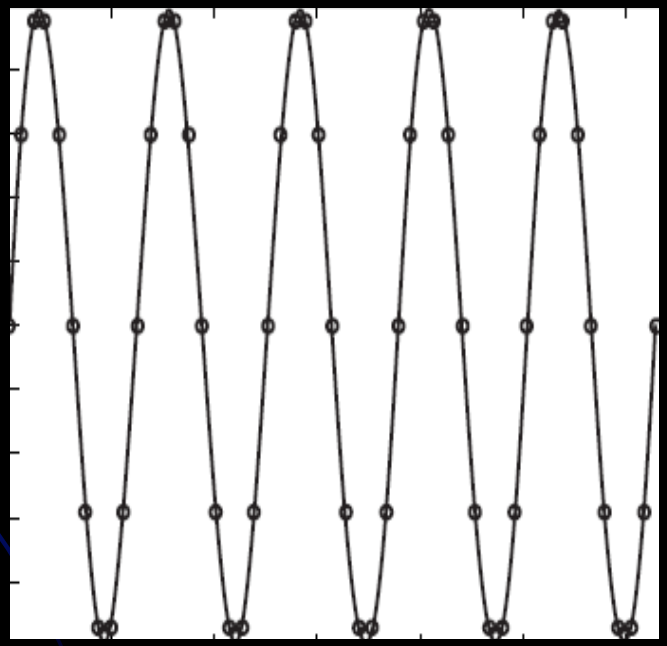




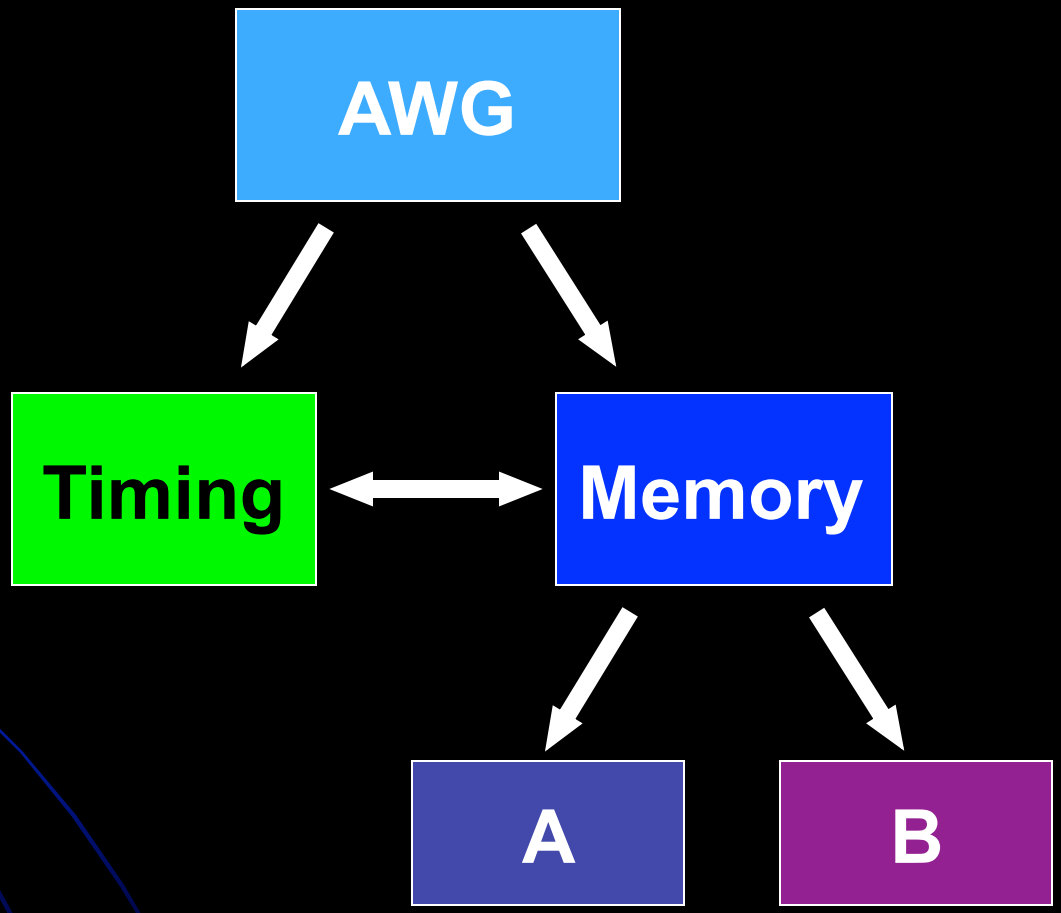


AWG Specification

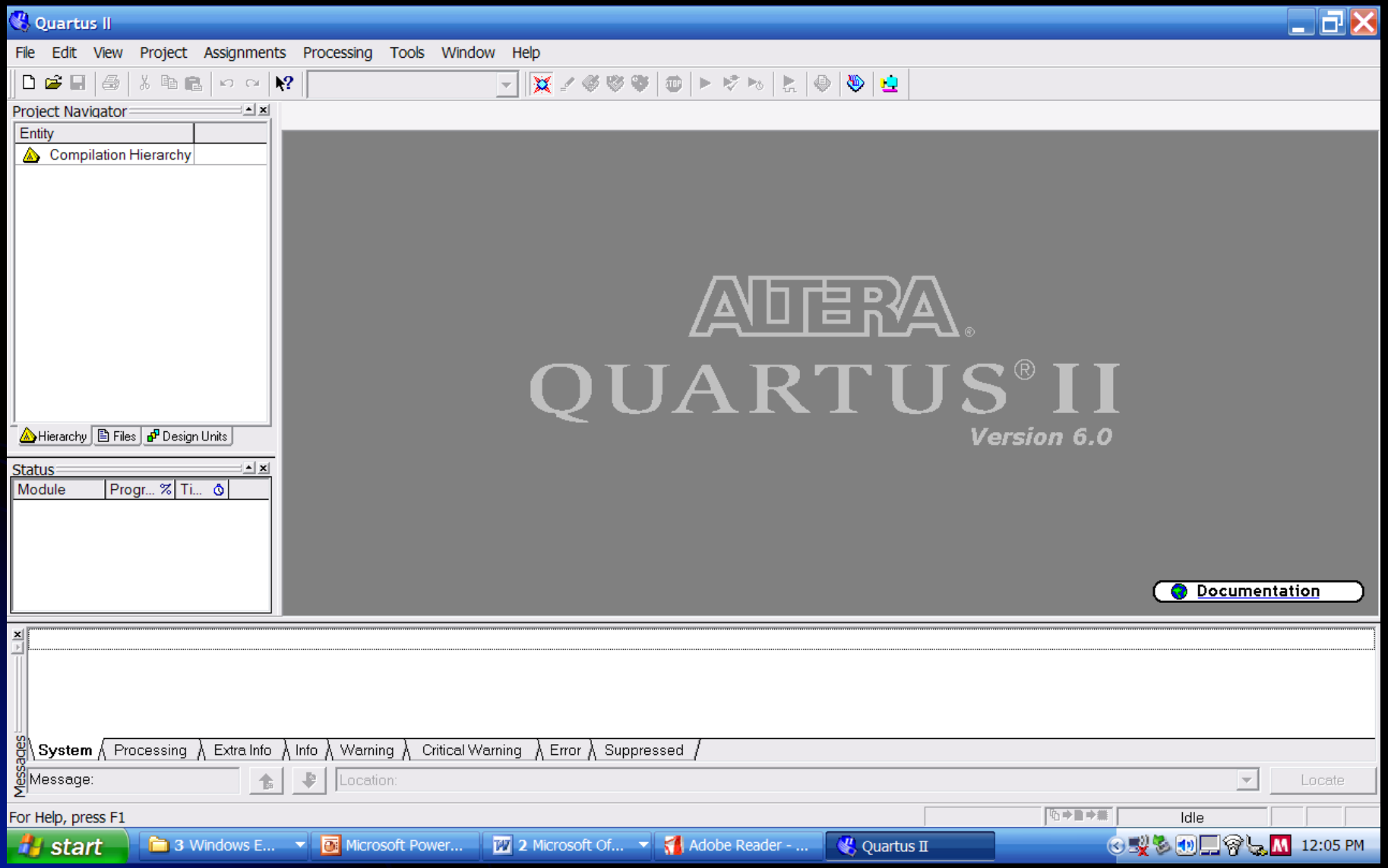
- Range of period – 100 Hz to 4 kHz
- Number of points – 1000
- Voltage resolution – 14 bits (DAC40 DACs)
- Update rate for new waveforms – 0.1 seconds (10 Hz)



Logic Block Diagram



Implement using Quartus II



Design Flow

Design Entry (VHDL) → Compilation → Simulation → Program Device

File Edit View Project Assignments Processing Tools Window Help

awgmemory

Simulator Tool | awgmemory.vhd | awgmemory.vwf | memoryA.mif | memoryB.mif

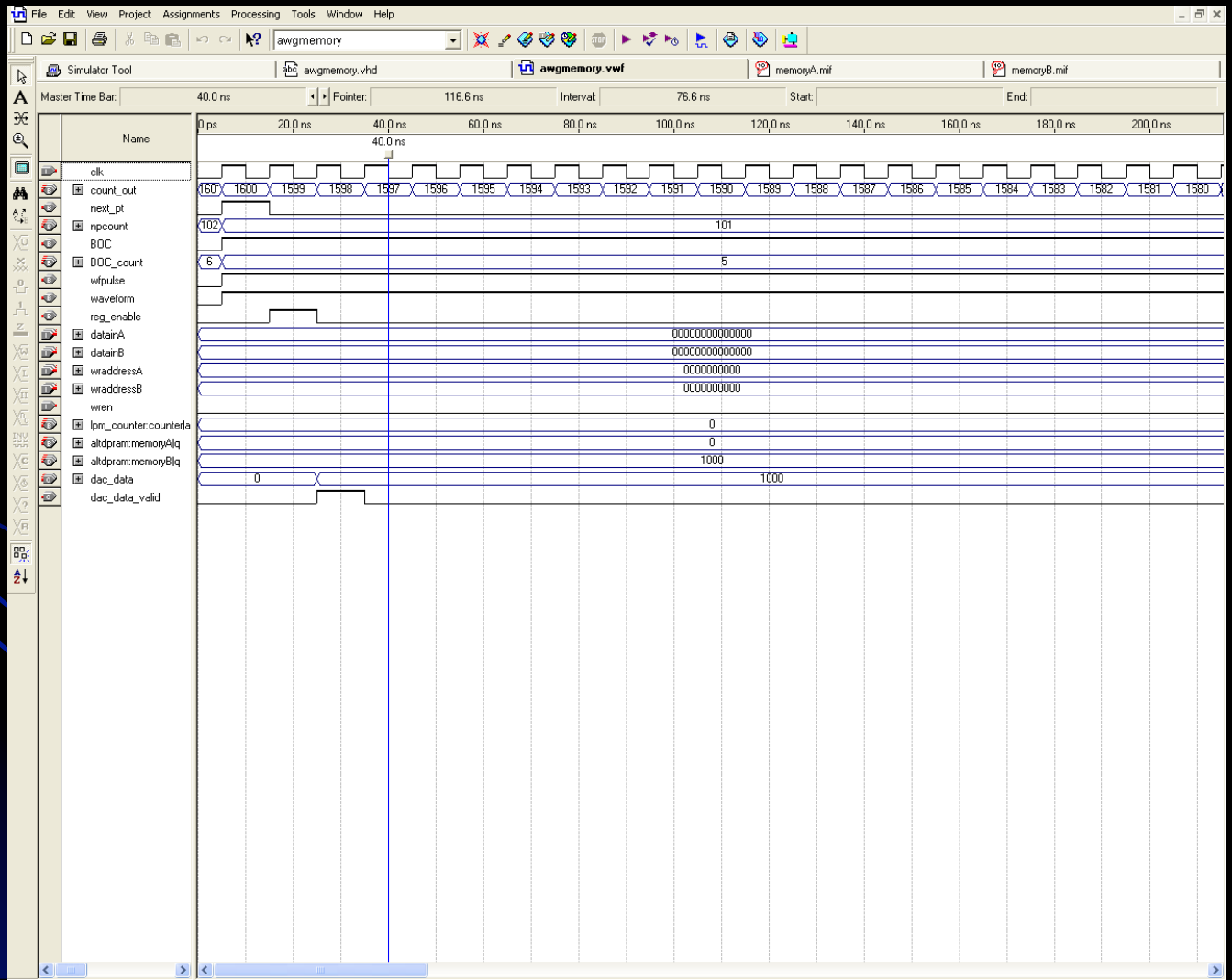
```
ARCHITECTURE behave OF awgmemory IS
    SIGNAL sclr        : STD_LOGIC;
    SIGNAL CT          : STD_LOGIC;
    SIGNAL address     : address_bus;
    SIGNAL dataA       : data_bus;
    SIGNAL dataB       : data_bus;
    SIGNAL data        : data_bus;
    SIGNAL reg_enable  : STD_LOGIC;
    --timing signals
    SIGNAL count_out : integer RANGE 0 TO 2047 := 1601; --1600 clock cycles
    SIGNAL npcount   : integer RANGE 0 TO 127 := 102;   --101 next_pts
    SIGNAL BOC_count : integer RANGE 0 TO 15 := 6;      --5 BOCs
    SIGNAL next_pt   : STD_LOGIC;
    SIGNAL BOC       : STD_LOGIC;
    SIGNAL wfpulse   : STD_LOGIC;
    SIGNAL waveform  : STD_LOGIC;
BEGIN
    counter : lpm_counter
        GENERIC MAP (LPM_WIDTH => 10)
        PORT MAP (clock => clk, sclr => sclr, cnt_en => CT, q => address);
    memoryA : altdpram
        GENERIC MAP (WIDTH => 14, WIDTHAD => 10, RDADDRESS_REG => "UNREGISTERED",
                     LPM_FILE => "memoryA.mif")
        PORT MAP (data => datainA, rdaddress => address, wraddress => wraddressA,
                  wren => wren, q => dataA, inclock => clk);
    memoryB : altdpram
        GENERIC MAP (WIDTH => 14, WIDTHAD => 10, RDADDRESS_REG => "UNREGISTERED",
                     LPM_FILE => "memoryB.mif")
        PORT MAP (data => datainB, rdaddress => address, wraddress => wraddressB,
                  wren => wren, q => dataB, inclock => clk);
    reg : lpm_ff
    GENERIC MAP (LPM_WIDTH => 14)
    PORT MAP (data => data, clock => clk, enable => reg_enable, q => dac_data);

    --GENERATE TIMING
    --next_pt counter - count 1600 clocks
    PROCESS (clk, count_out)
    BEGIN
    IF (clk = '1') AND (clk'EVENT) THEN
        IF (count_out = 1601) THEN
            next_pt <= '1';
            count_out <= count_out - 1;
        ELSIF (count_out = 1) THEN
            count_out <= 1600;
            next_pt <= '1';
        ELSE
            count_out <= count_out - 1;
            next_pt <= '0';
        END IF;
    END IF;
    END PROCESS;

    --BOC counter - count 101 next_pts
    PROCESS (next_pt, npcount)
    BEGIN
    IF (next_pt = '1') AND (next_pt'EVENT) THEN
        IF (npcount = 102) THEN
```

Simulate Design

Design Entry (VHDL) → Compilation → Simulation → Program Device



Conclusion

Dual-stroke waveform concept

- Efficient – Only 1 wavefront sensor
- Astronomical objects appear 2.5X brighter

In the Future

- Interface DAC40 to oscilloscope
- Test AWG
- Implement in next generation AO system

Acknowledgements

- Stephen Colley
- Olivier Guyon – Subaru Astronomer
- Hideki Takami – AO Project Manager
- Subaru Telescope (NAOJ)
- Center for Adaptive Optics
- Funding provided through the Center for Adaptive Optics, a National Science Foundation Science and Technology Center (STC), AST-987683