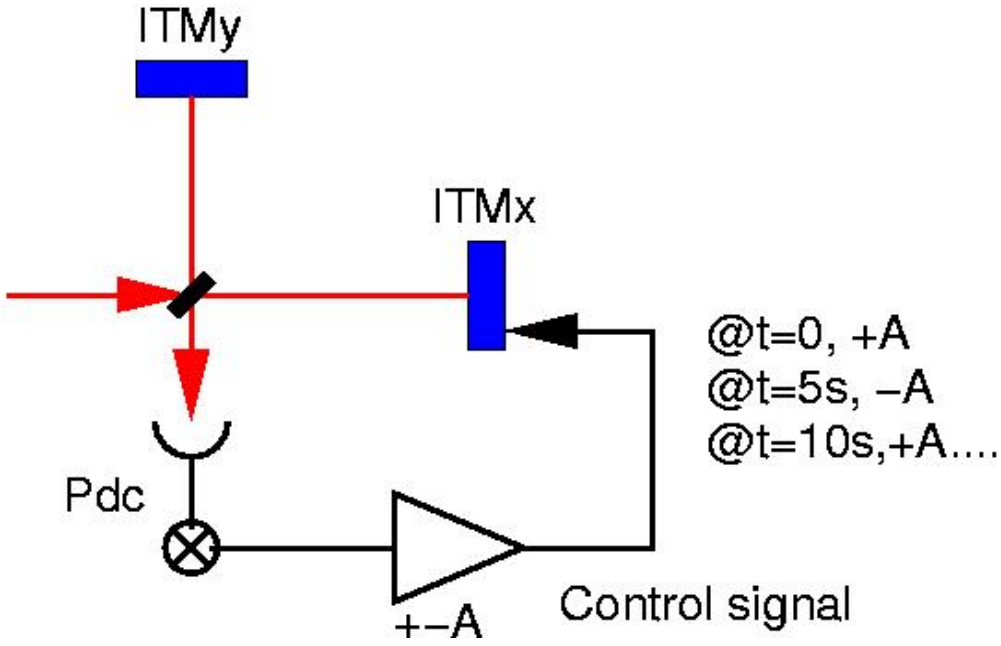
Calibration Procedures: E2E and Observations

Focusing on "DC" calibrations of ITMs

- Investigation of two methods
  - Counting of fringes
  - Toggling of the control loop sign
- Methods tested and compared using the 4k at LHO
- Automated procedures: ~2% precision level reached (statistical)
  - Accounting for (some) systematic error contributions...
- Analysis of E2E data

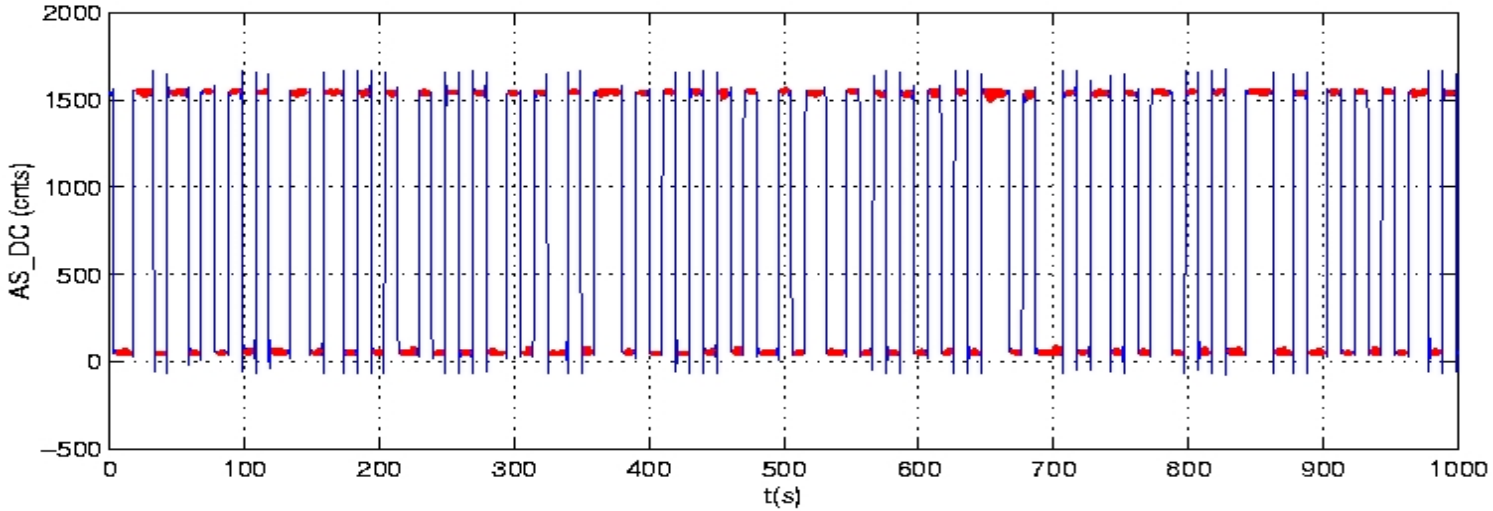
Sign Toggling Method

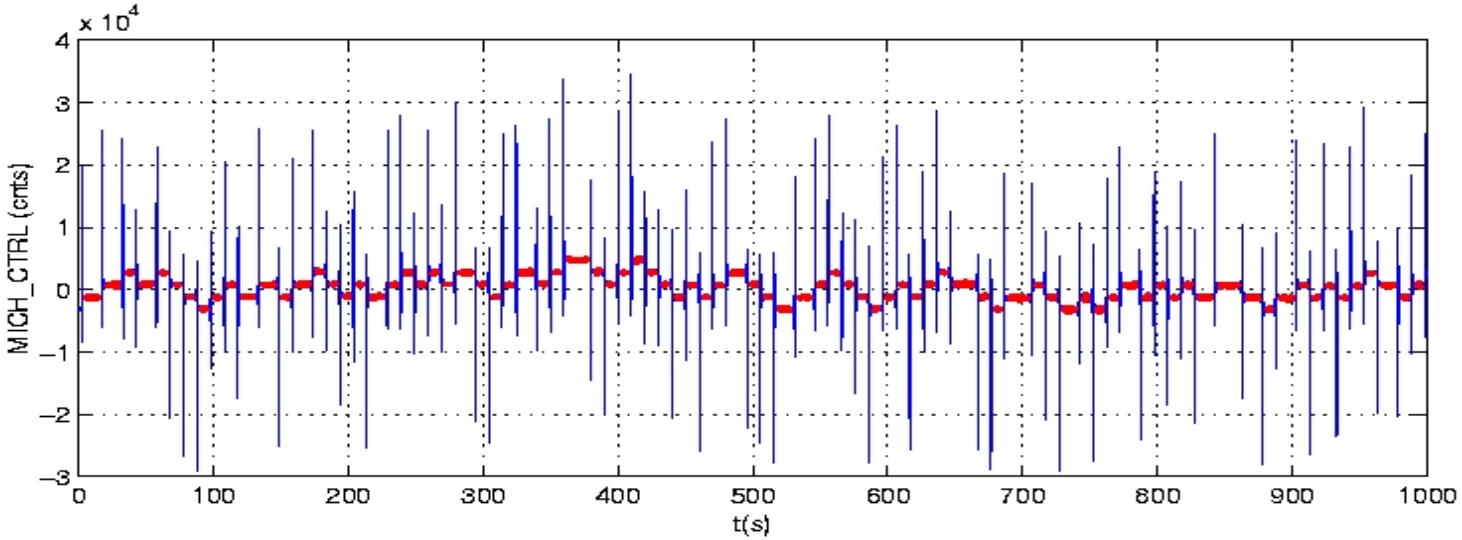
- Lock simple Michelson



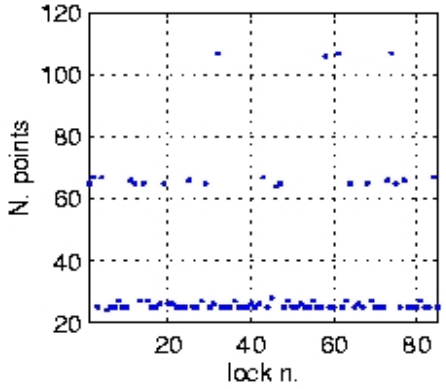
- Toggle servo sign
  - Dark <–>Bright fringe (lambda/4)
- Calibration of control signal

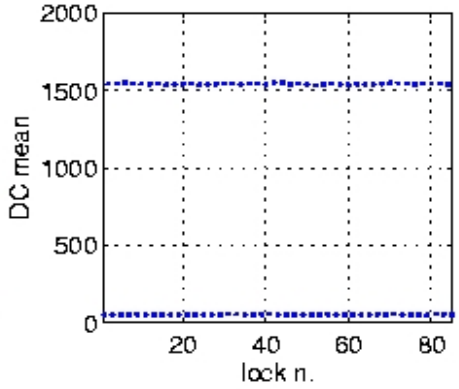
Sample Data

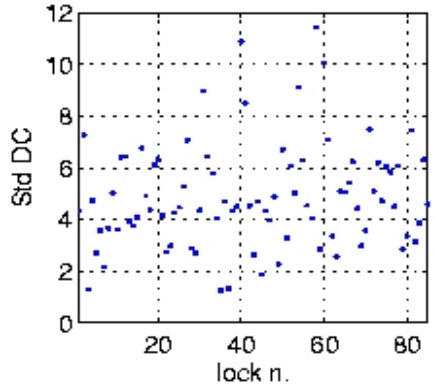

AS_DC (cnts)
2000
1500
1000
500
0
−500
0
100
200
300
400
500
600
700
800
900
1000
t(s)

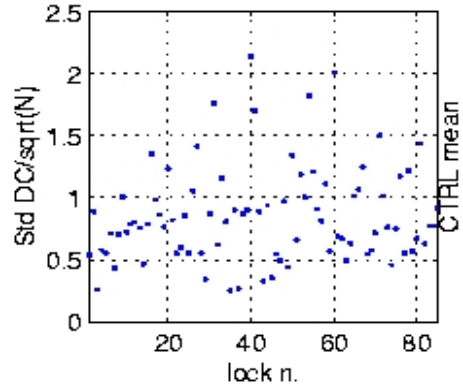

x 10^4
MICH_CTRL (cnts)
4
3
2
1
0
−1
−2
−3
0
100
200
300
400
500
600
700
800
900
1000
t(s)

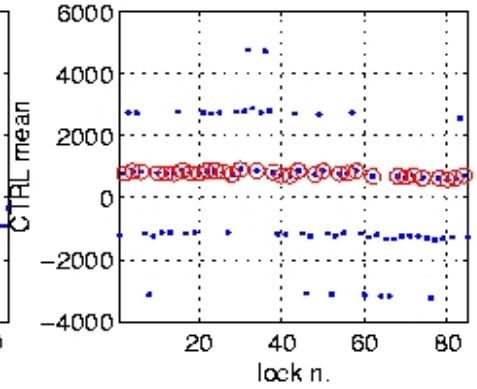
Data Analysis

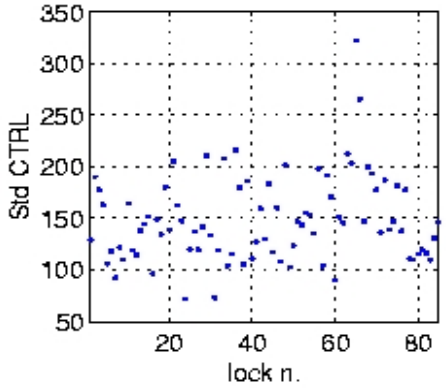


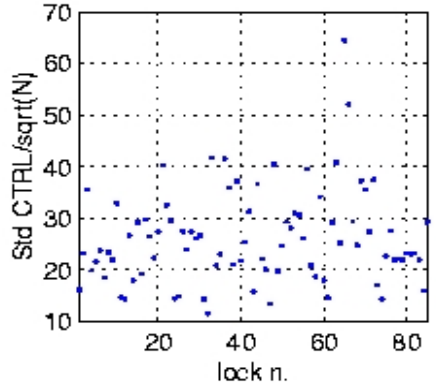


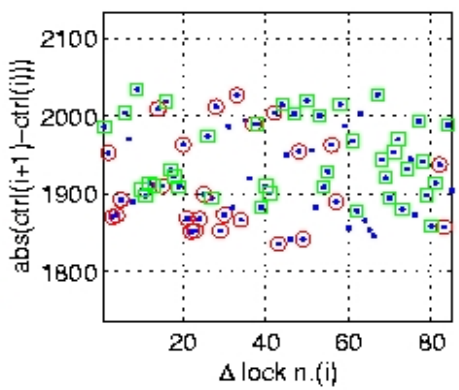












Mean (cnt) = 1929.0897 +– 56.5569

---> (1.3789e−10 +– 4.0426e−12) [m/cnt]

Mean UP(cnt) = 1912.192 +– 60.9865

Mean DOWN(cnt) = 1946.161 +– 49.9954

Mean SUM(cnt) = 3858.3531 +– 78.86

---> (1.3788e−10 +– 2.8182e−12) [m/cnt]

Results

- ITMx calibration R (using all transitions − statistical):

  (1.38 +− 0.04) * 1e−10 [m/cnt]

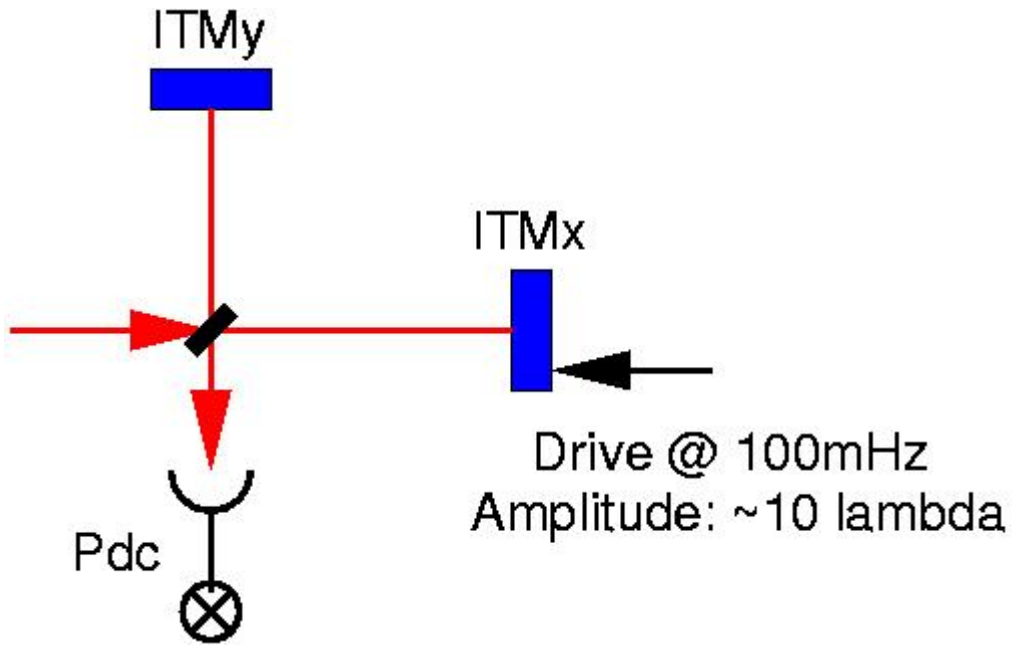
- ITMx calibration R (summing the lambda/4 transitions, eliminating presence of offsets − statistical):

  (1.38 +− 0.03) * 1e−10 [m/cnt]

- Comments
  - Automated procedure
  - Pure DC calibration
  - Drive calibration within the lambda range (IFO operation)
  - Not sensitive to signal offsets

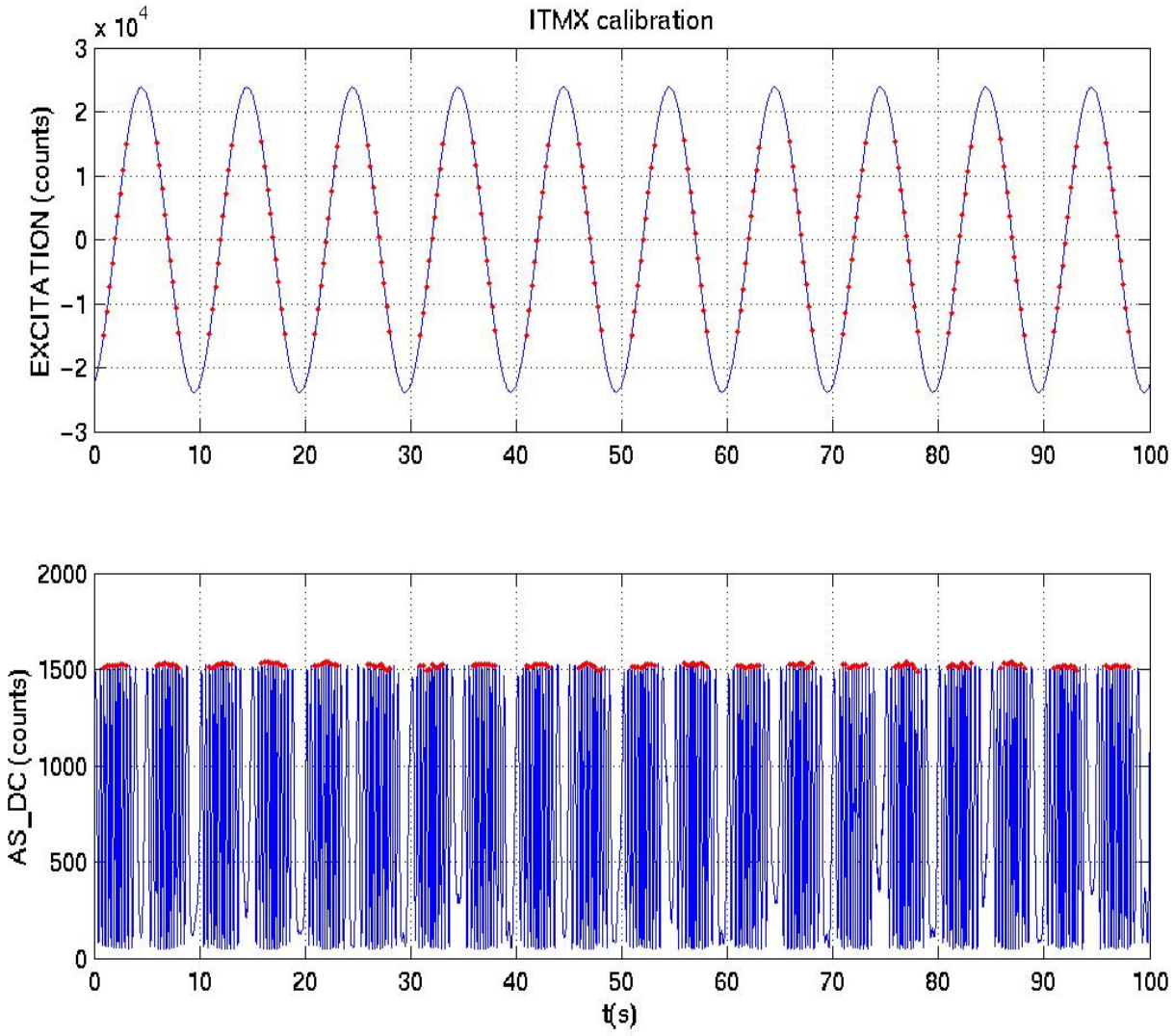
Fringe Counting Method

- Masses free swinging
- Driving ITMx

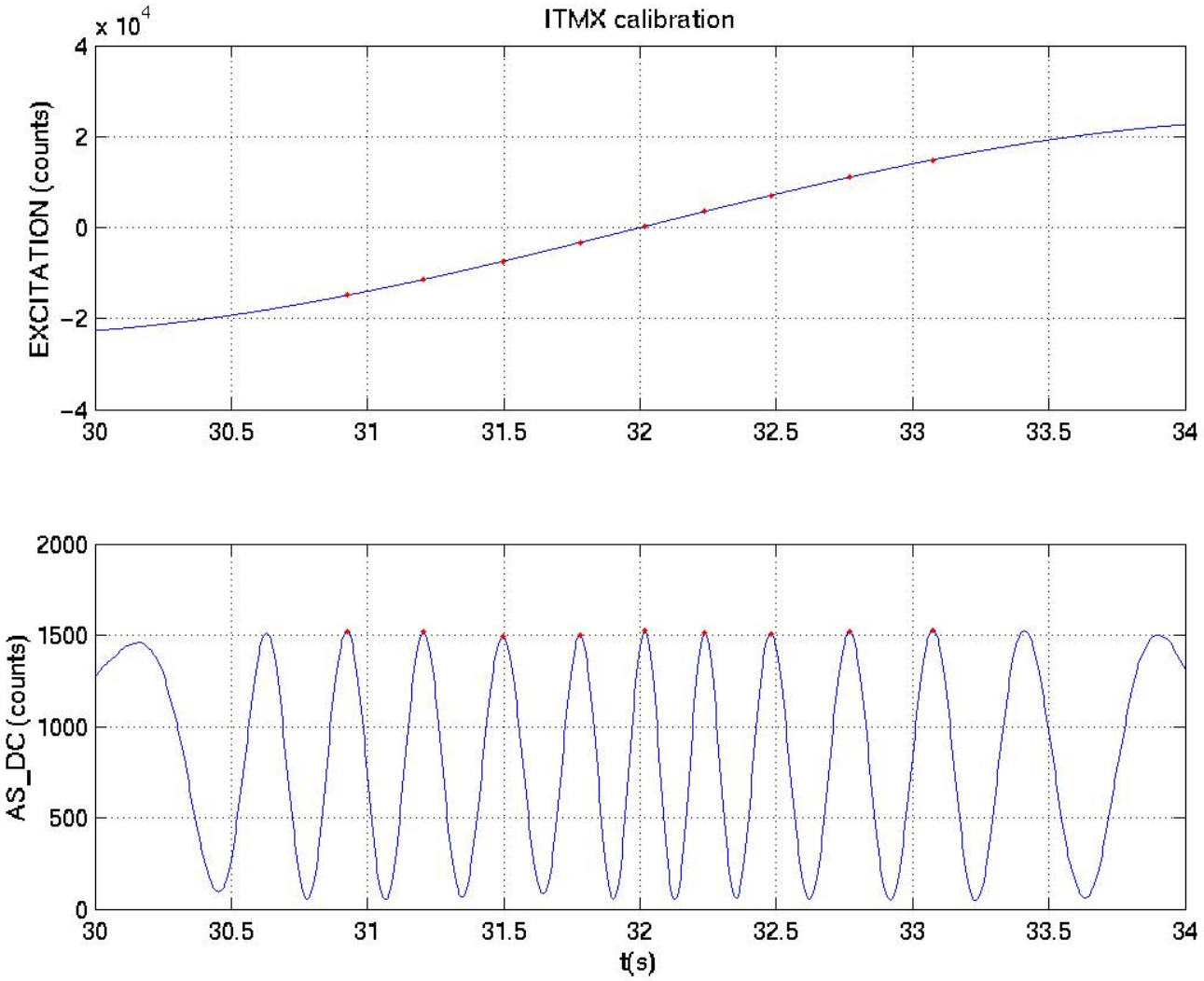


- Counting fringes and calibrating drive

Sample data



Sample data


ITMX calibration
x 10^4
EXCITATION (counts)
4
2
0
−2
−4
30
30.5
31
31.5
32
32.5
33
33.5
34
AS_DC (counts)
2000
1500
1000
500
0
t(s)

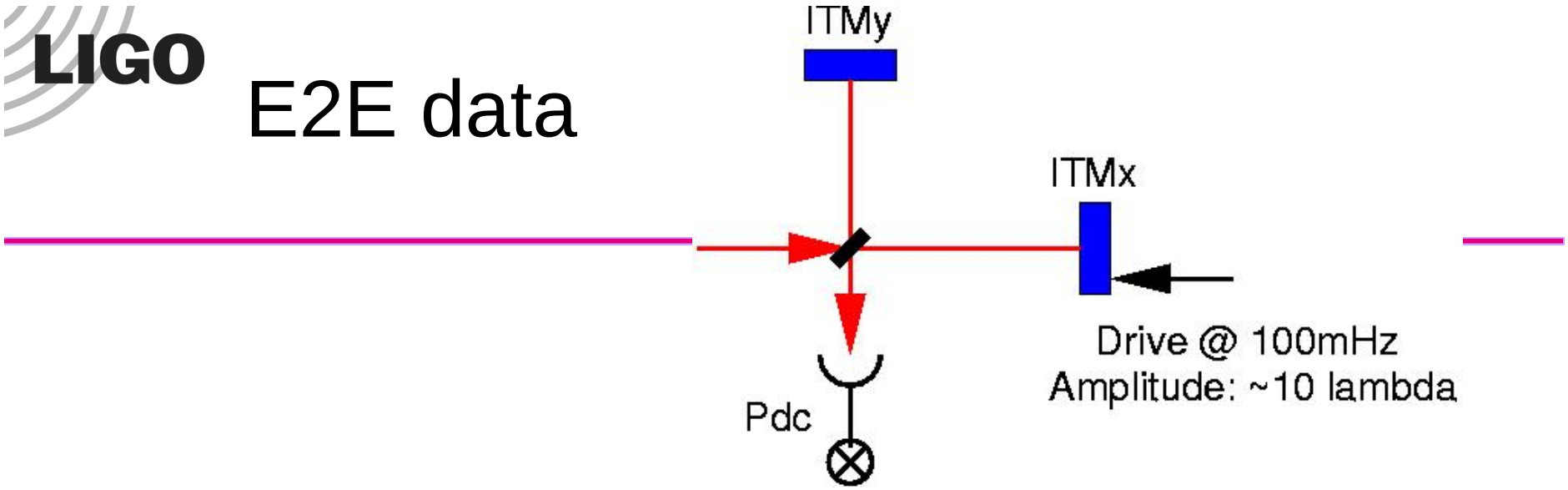
Results

- ITMx calibration R
  - » *Fringe Counting* Method

    (1.44 +– 0.02) * 1e–10 [m/cnt]
  - » *Sign Toggling* Method

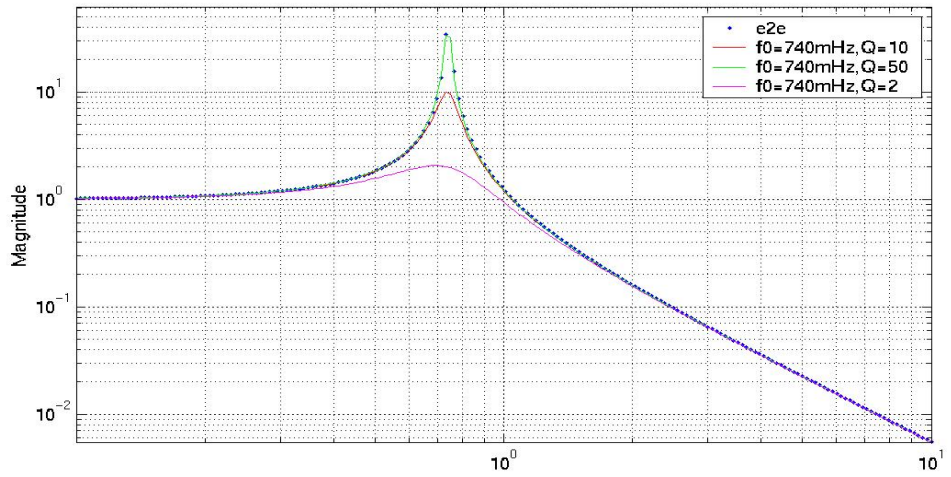
    (1.38 +– 0.03) * 1e–10 [m/cnt]
- Comments
  - » Parabola Fit of AS_DC peaks applied
    - – Even if not necessary if mean is taken
  - » Drive excursions >10 lambda
  - » ***Both methods yield precise results (1–2%) BUT differ by 5%***

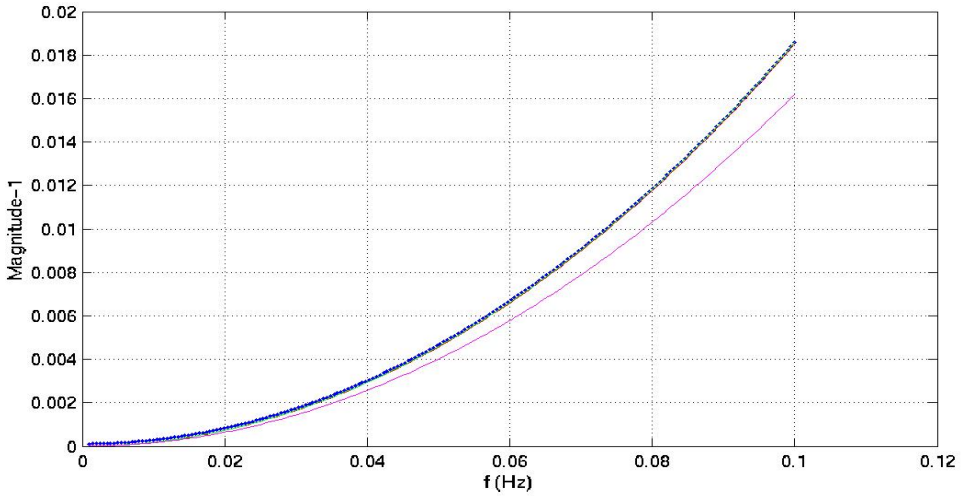
E2E data



- Modeled the "fringe counting" procedure
  - » Suspensions: 1D, digital filter (f0=740mHz, Q=10)
  - » Optics module
  - » No injection of noise (seismic,..)
  - » Driving @ 100mHz, sweeping ~10 fringes
- Results from E2E data
  - » Analysed data with the same programs used on the real data
  - » Discovered that the observed calibration factor R' differs by ~2% from the nominal calibration factor R (R'>R)

Actuator TF:
mag(100mHz)*98%=
mag(1mHz)





Conclusion

- Both methods yield precise results (1−2%)
- Contribution of (some) systematic errors accounted for
  - » ITMx calibration R
    - – *Fringe Counting* Method

      (1.44 +− 0.02) * 1e−10 [m/cnt]
    - – *Fringe Counting* Method −− correcting for the actuator mechanical response

      (1.41 +− 0.02) * 1e−10 [m/cnt]
    - – *Sign Toggling* Method

      (1.38 +− 0.03) * 1e−10 [m/cnt]