Beam Steered AO Deflectors.

An AO deflector output is scanned by varying the RF drive frequency. The power in the scanned beam is by controlled by varying the RF amplitude. An ideal acousto-optic deflector would generate a uniform scan efficiency over the full deflection range. In practice this is difficult to achieve. The optimum laser input angle (or Bragg angle) is frequency dependent. This creates roll-off in the scanned beam efficiency as the drive frequency is altered to create the scan. (See Fig 2, "Simple" curve)

Bragg Angle

First order deflection efficiency is maximised when the laser beam input angle (θ) relative to the acoustic column axis satisfies the Bragg condition:

$$\theta_{Bragg} = \frac{\lambda.fc}{2.v}$$

The output scan angle is given by a similar relationship:

$$\theta_{scan} = \frac{\lambda.(fc \pm f)}{v}$$

where :
λ = optical wavelength
v = acoustic velocity
fc = centre frequency
f = frequency deviation

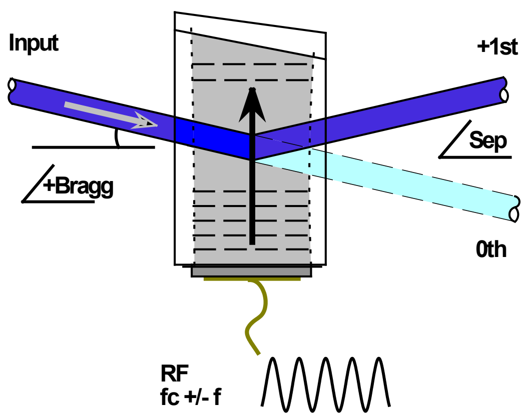


Figure 1

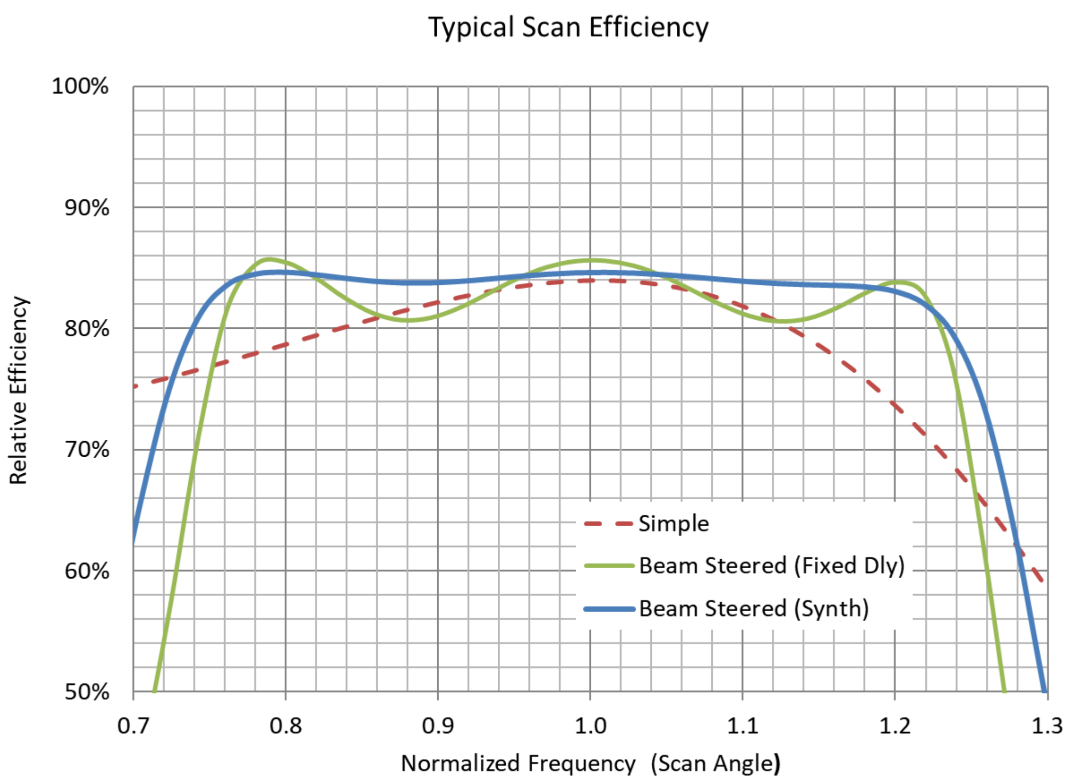
The Bragg angle can only be exactly true for one chosen drive frequency (fc). However for an AO deflector, the drive frequency (f) is swept about a centre frequency (fc) to create the scanned output beam. For drive frequencies other than fc, the output efficiency of a normal single electrode AO device will reduce due to the resultant Bragg angle error.

The transducer characteristics of such AO deflectors are designed to minimise this effect. However, to remain within the Bragg regime there is a limit to the amount of bandwidth a simple AO device with single electrode can provide.

To circumvent this difficulty and achieve greater bandwidth and hence scan angle, several techniques exist to ‘beam steer’ the acoustic wave in the AO crystal material and thus track the optimum Bragg conditions over a wider range of frequencies.

The plot below gives illustrates the benefits of acoustic beam steering.

Figure 2



Electronic Beam Steering

The most reliable method uses an array of electrodes on the transducer, each with an RF signal progressively shifted in phase. The result is a change in the launch angle of the acoustic beam in the AO crystal depending on the RF drive frequency.

By using the appropriate phase shift and electrode spacing, the acoustic active beam steering can be made to track the ideal Bragg angle at every frequency across the scan range. (See Appendix)

Beam steering techniques are used in many Isomet AO deflectors including: D600-G50, D110-T100, D1319-T220, D1135-T110, D1315-G50L, D1384-aQ120 and LS700-G70

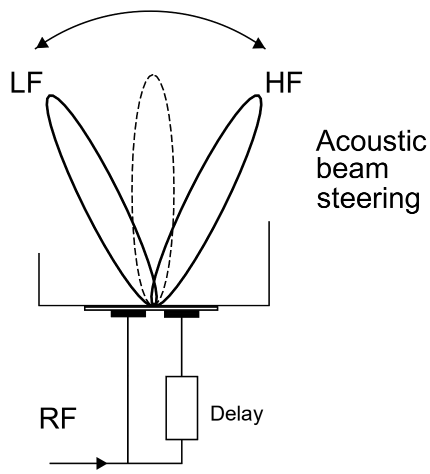


Figure 3

The “beam steered“ AOD deflectors are characterized by multiple RF inputs, typically 2 or 4. At any given time the same frequency and RF amplitude is applied to all RF inputs. However the phase differs and this phase offset value is generated in the RF driver depending on the tuned frequency.

There are two means employed to generate the phase control:

- **VCO tuneable driver and fixed delay line(s).**
  The time delay results in phase change between electrodes proportional to the drive frequency. This is the simplest solution but the phase match is only exact at two points. (See Fig 4). A small increase in RF power can, in some cases, compensate for the remaining Bragg angle error.

  Example drivers are RFA3085-2, RFA3110-4, RFA3050-2

- **Programmable iMS4 Synthesizer**

Multi-output DDS frequency sources offer precise phase control and allow optimum Bragg match across the full RF bandwidth of an AO deflector.

Exact phase-frequency control typically results in lower RF power dissipation and flatter efficiency sweep compared to the simpler delay line approach.

Examples: iMS4-P (or -L) synthesizer,
with power amplifiers such as RFA0110-2, RFA1170-4, AN0-series

In a typical application, the iMS4 is pre-programmed with a Look-Up-able. This is a calibration file that contains the exact phase and amplitude data required to generate a scan with uniform intensity. Once programmed the iMS4 automatically applies this compensation according to the demanded frequency.

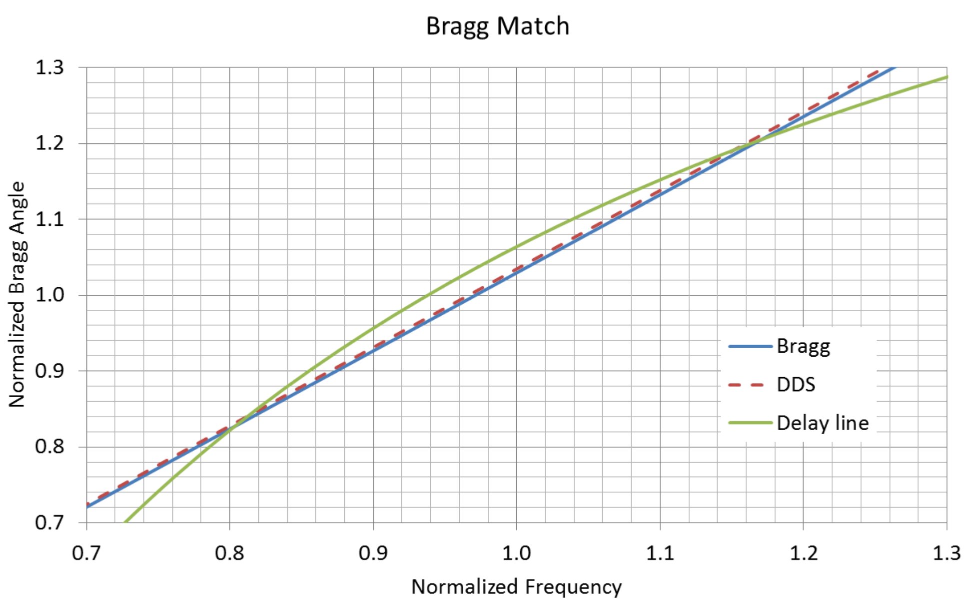


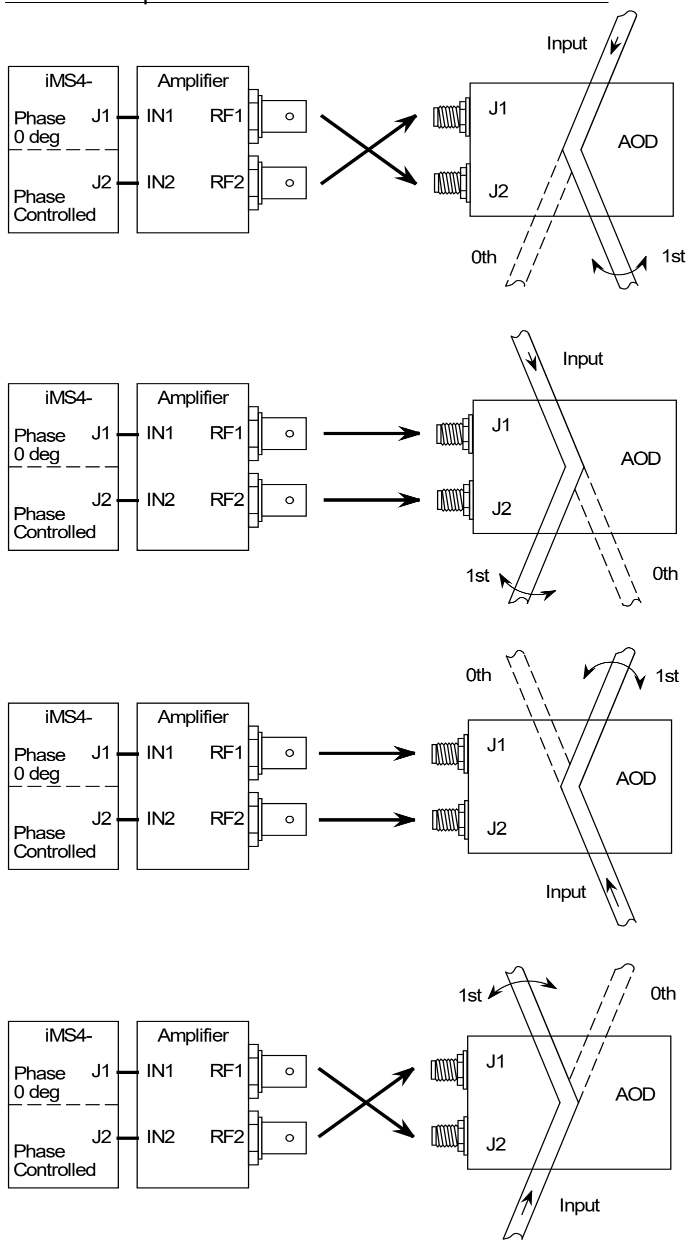
Figure 4

For either method above, tuning the frequency will result in a continuous monotonic line output. If significant peaks and troughs are noted across the sweep, it is probable that the phase delayed output(s) of the driver-amplifier are connected to the incorrect inputs of the AO deflector. (see Fig 5).

The coax cables between the outputs of the driver-amplifier and beam steered AO deflector should be equal length unless otherwise instructed. Unequal lengths of more than a 1cm would introduce a phase error. Within limits, small changes in the relative lead lengths can be used to fine tune the deflector sweep response, although this is not usually required. The Bragg angle would need re-adjustment.

iMS4- with 2-section beam steered AO deflectors

Connection options for Beam Steered AO Deflectors



Correct orientation as viewed from top of AOD

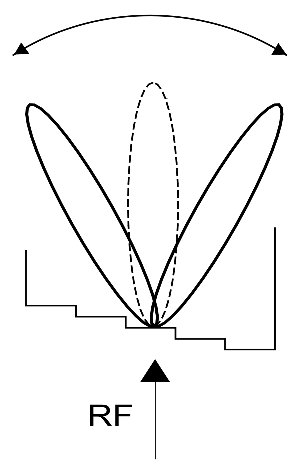
(Connector type and identification may differ)

Figure 5: Connection order dependence on the selected Bragg orientation

Mechanical Beam Steering

An alternative technique applies a stepped transducer to create the phase delay.

Bonding a stepped transducer onto a crystal is not as straightforward. The steps place certain limitations on the bonding method that can be employed. The net result is that such transducers are often RF power limited.



Isomet does not use this method.

Appendix

Phase Steering Formula

The formula for determining exact phase matching in a longitudinal mode beam steered AOD is (in radians):

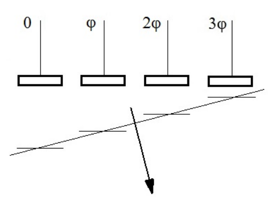
$$\varphi(f) = \pi \cdot \left[\frac{D \cdot \lambda o \cdot 10^{-3}}{va^2 \cdot no} \cdot f^2 \cdot \left(1 - \frac{f1}{f}\right) \right]$$

This is the same regardless of the number of electrodes.

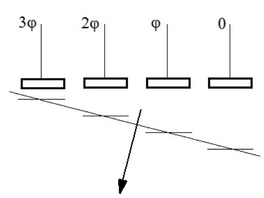
Example figures

	Model	D1135T-110	D1312-T80 D1412-T80 D1422-T85	D1365-aQ180 *D1384-aQ120*	D1384-aQ170	D1445-T180 *D1445-T220*
	Number of electrodes	4	2	2	2	2
D	Distance between electrodes (mm)	6.1	10.5	12.0	8.5	4
no	Refractive index	~2.2	~2.2	~1.55	~1.55	~2.2
f	Frequency (MHz)					
f1*	Frequency at desired center (MHz)	110 +/- 10	80 +/- 10	180 +/- 10 *120 +/- 10*	170 +/- 10	180 +/- 10 *220 +/- 10*
λo	free space wavelength (um)					
va	acoustic velocity (mm/us)	4.2	5.7	5.7	5.7	4.2

When φ(f) is positive, the arrangement is:



and when negative,



* Typically, f1 is selected to provide a balance between + and - phases required over the AOD sweep bandwidth