Airborne Lidar for *National Lidar Mapping Initiative*

Laser subsystem
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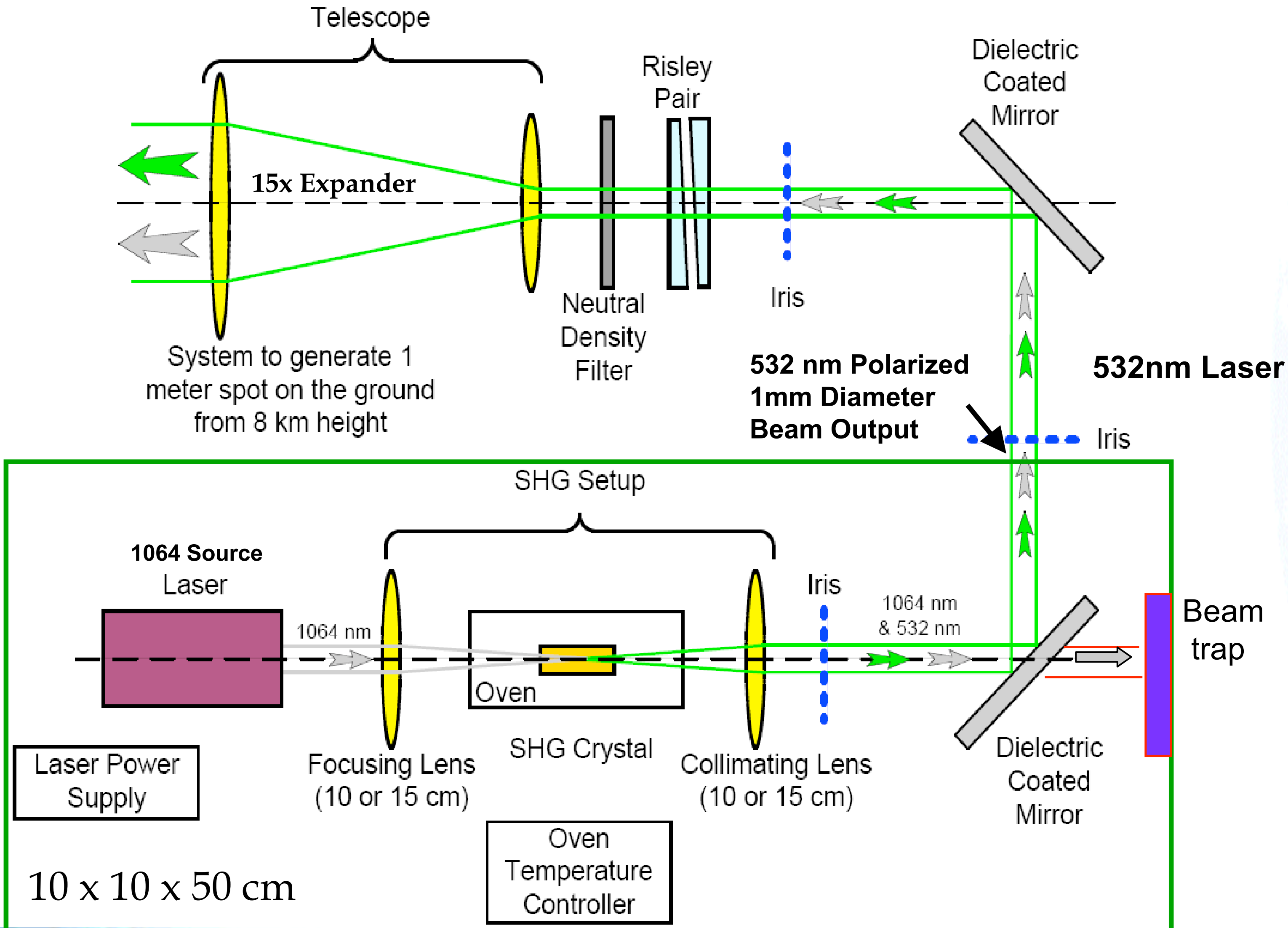
Thanks to Tony Seas and Tammy Brown for their help on ISAL study of this laser subsystem

Baseline design of laser subsystem



Baseline Laser Requirements and design

- **Seven independent 532nm green lasers, each split into 5 spots => total 35 spots**
- **1064nm => SHG by PPKTP => 532nm with efficiency >50% (state of the arts: 65%)**
- **Key specs of 1064nm laser purchased from IPG:**
  - high peak power >=10kW;
  - Narrow linewidth =<0.1nm (or 26.5GHz);
  - PM (ER > 13dB);
  - Beam Quality M2<1.4 (note that the above specs are required also for SHG);
  - High wall-plug efficiency: ~5%-10%;
  - ON/OFF extinction ratio (ER): >30dB;
  - Out of band power spectral density: <-20dBc;
  - Pulse repetition frequency (PRF): 0.1 MHz to 2MHz;
  - Stable center wavelength;
  - Power stability: <5%;
  - Optical output pulse trigger: internal and external;
  - Electrical trigger signal synchronized with optical output pulse;
  - GPIB interface;
  - Operating temperature: 0 to 45C;
  - Can survive and operate on an airborne platform (such as a DC-8 airplane);
  - 19” rack mountable: Controller box 19”x17”x5.5” (30lb) + laser head 3”x5.5”x 12”(8lb).

Ytterbium Fiber Laser Tradeoffs

- **1064nm pulsed narrow-bandwidth PM Yb fiber laser is well suited for this mission**

Advantages:

- High wall plug efficiency >5%;
- Smaller size;
- Lower cost;
- minimum thermal load => air cooled;
- Excellent beam quality (no thermal lensing);
- No alignment needed ;
- Closed cavity => contamination free;
- High reliability and maintenance free ;
- Less susceptible to vibration;
- Wavelength flexibility.

Disadvantages:

- Lower peak power due to small fiber size needed for wave-guiding;
- Does not like high peaks in both time domain and frequency domain;
- small core size of fiber + long fiber length => Non-linear effects (linewidth broadening, SBS at single frequency, etc).

Alternative Design: Shared YDFA (WDM)

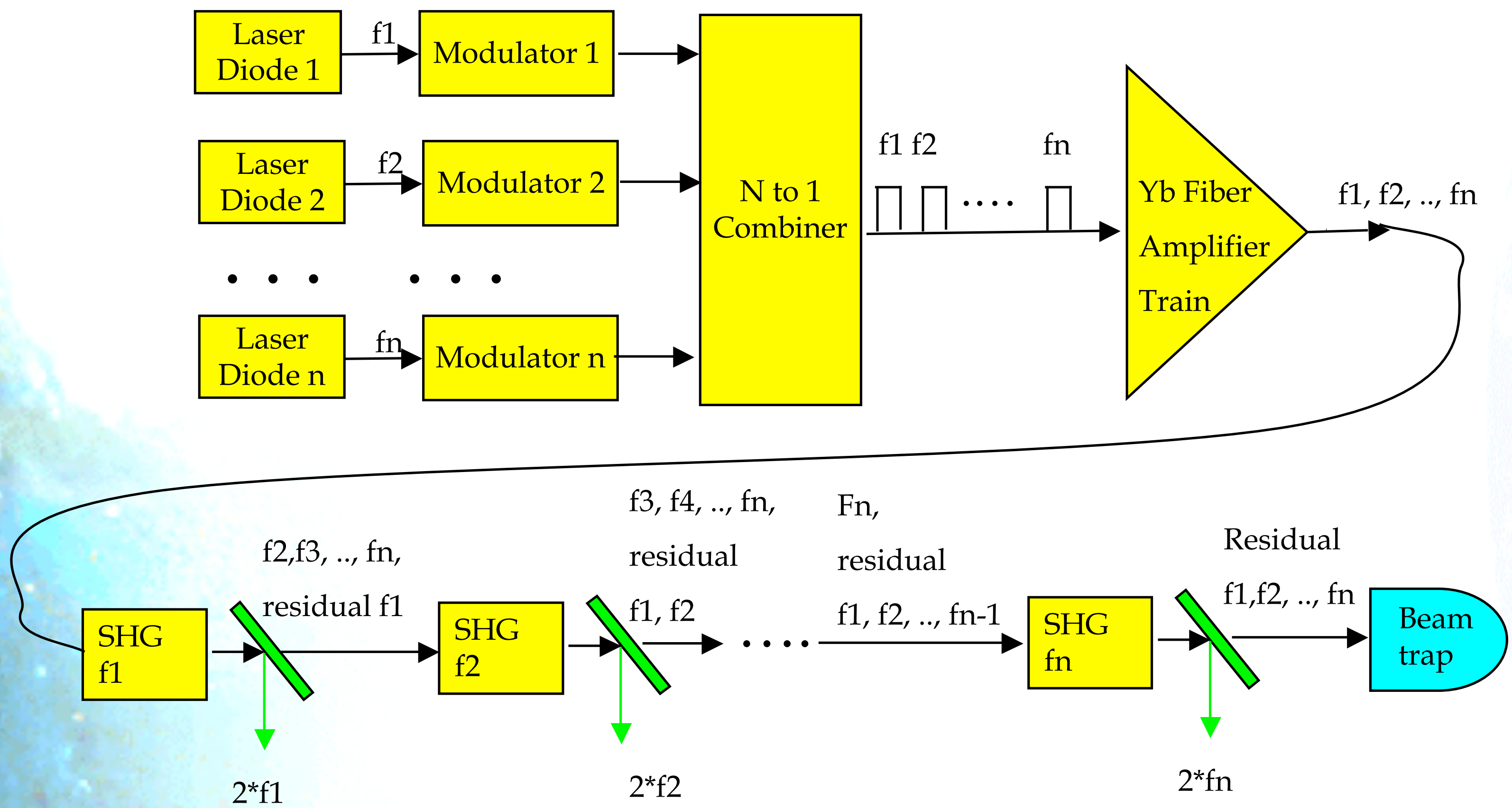


Figure 2. Multiple modulated seed sources, each operating at different frequencies f1, f2, …, fn and each pulsing at different time slots, are first combined and then amplified by one Yb fiber amplifier train. The amplified pulses further undergo cascaded SHG as shown. SHG crystals serve as narrowband WDM filters and frequency converters, enabling generation and separation (demultiplexing) of n frequency doubled channels (2f1, 2f2, …, 2fn).

Alternative Design: Shared YDFA (WDM)

- Optical frequencies of laser diodes (f1, f2, ---fn) are separated by more than the SHG bandwidth Δf such that each SHG crystal doubles one laser line and transmit other laser lines with little attenuation;
- Pulses from different laser diodes are offset (e.g., equally spaced) to avoid overlap in time domain => peak power remains the same as the single frequency channel case;
- The amplified output is then coupled to a cascaded SHG crystals, each tuned to the one of the diode laser wavelengths, f1, f2,…, or fn.
- The first SHG crystal frequency doubles the f1 line to frequency 2*f1, the second SHG crystal doubles f2, so on and so forth, and finally the last SHG crystal doubles fn.
- The dichroic mirror inserted right after each SHG crystal picks off the frequency doubled beam generated by that SHG crystal, and allows f1, f2, …fn lines to pass to the next stage.
- The average output power of the fiber amplifier is multiplied by n, the peak power stays unchanged => avoid shortcoming of fiber laser.
- This scheme works for short and long pulses, and even for CW operation.
- Frequency spacing of f1, f2, …, fn can be made unequal to avoid possible four-wave mixing.
- This scheme can be extended to other frequency conversion applications, such as third harmonic generation, OPO, and OPA, etc, as long as each frequency converter has a narrow band and converts the in-band beam and passes the out-of band beams.

Alternative Design: Shared YDFA (WDM)

- **Advantages**
  - Reduced parts counts and cost;
  - Reduced complexity, size and mass;
  - Scalable to high channel count (n) => reduced # of spots split from each channel => increased pulse energy on each split pots;
  - Allows lower peak power and thus less linewidth broadening => enables single frequency operation.
  - More compact SHG arrangement;
  - Frequency offset reduces channel cross talk at the receivers;
  - Many more.

technical readiness and concerns

- SHG with PPKTP (1064nm =>532nm) is well developed => minimum risk;
- IPG's 1064nm pulsed narrow-bandwidth PM Yb fiber lasers/amplifiers have been well developed at average power levels up to a few hundreds of Watts and represent state of the arts;
- Similar lower power version of IPG Yb fiber amplifier had undergone space qualification tests at MIT Lincoln lab for MLCD;
- The longest lead time items are the 1064nm fiber lasers(~5 months);
- Two year development time is adequate for laser sub-system.
- Concerns: Some components of this type of fiber lasers, such as fiber coupled isolators, had failed vibration + humidity + temperature tests. The component quality has since been improved though.

Night time operation

- Night-time operation may relax the requirements on the lasers;
- Night-time operation allows broader linewidth => higher peak power => reduced # of lasers or channels.

Conclusion

- Yb fiber laser is well suited for this mission;
- Yb fiber campfires/lasers are well developed;
- SHG with PPKTP is a mature technology and thus poses minimum risk;
- Two year development time is adequate for laser subsystem;
- A alternative WDM design is reported that requires only one Yb fiber amplifier to do the job of multiple lasers;
- This WDM design offers many advantages over the multiple fiber laser design and thus deserves serious consideration.

Backup slide: Alternatives Design-- Shared Seeder

- **All seven 1064nm Yb fiber lasers share one seeder (laser diode + preamplifier) which is split (with PM fiber splitter) seven ways:**

  advantages
  - Reduced parts counts and possibly cost;
  - Simplified timing scheme – all 35 spot pulses tied to one timing signal.

  disadvantages
  - No timing independency among seven lasers;
  - No wavelength independency among seven lasers;
  - Customization needed.
- **Possibility of using fiber coupled wave-guided SHG technique => all fiber design => to ease layout/alignment difficulty.**